DIGITAL VOLTMETERS

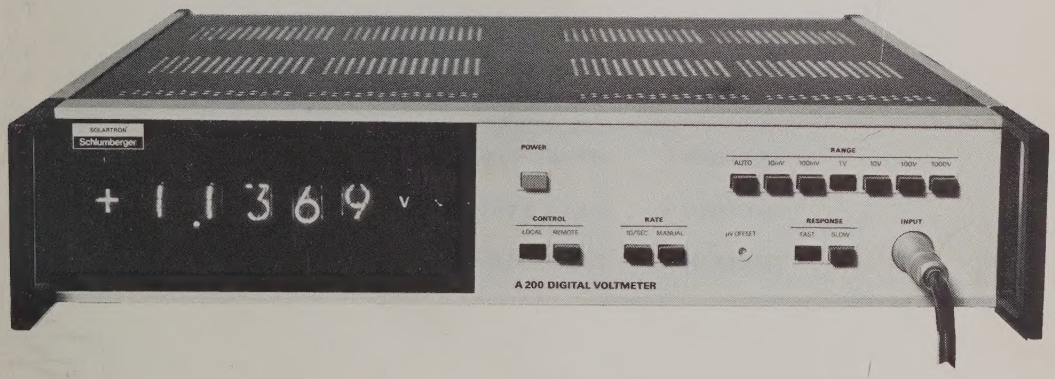
A200
A203
A205
A220
A223
A225
A227

Schlumberger

OPERATING MANUAL

DIGITAL VOLTMETERS

A200 A220
A203 A223
A205 A225
A227



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OPERATING MANUAL

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INTRODUCTION

Your new digital voltmeter (dvm) is the latest in a series of sophisticated and advanced instruments. Solartron design experience has made available an accurate and sensitive range of voltmeters which, when fitted with a fan out unit, are fully programmable by remote commands.

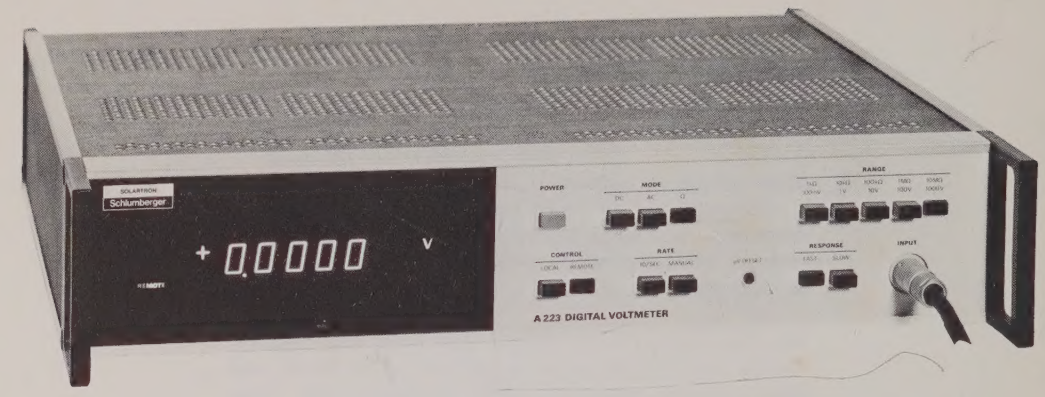
The functional control layout and clear, unambiguous display make this a simple to use dvm whilst the AC and Ohms options make the basic instrument even more versatile.

This manual contains all the necessary information on how to operate your dvm; read it carefully so that you can use the dvm to its full capability.

The Display

Some instruments use a type of display different from those illustrated in this manual. An example of an instrument with the alternative display is shown overleaf.

All information given in this manual applies to instruments with either display.



A Type A223 using a 7 Bar Neon type of display.

As well as the shape of the numerals, the appearance and positioning of the annunciators have also changed.

The following are in column to the extreme left of the display.

WAIT — Indicates an invalid display. A measurement is true when this indicator is extinguished.

O/L — Overload, in conjunction with a display of 19999.

~ — AC value displayed.

REMOTE — The instrument is under remote control.

The polarity signs, + and −, lie between the annunciator column and the numerals. The units annunciators are to the right of the numerals.

Indicator

Displays units (mV or V), WAIT and REMOTE.

WAIT is displayed to indicate that the display has not been updated with the result of the latest measurement.

1) When a MANUAL sample has been initiated whilst the voltmeter is in the SLOW RESPONSE mode.

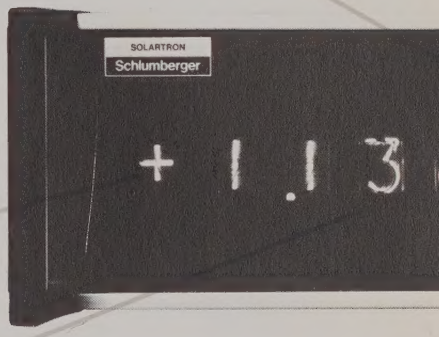
2) When the voltmeter is AUTO ranging with SLOW RESPONSE.

WAIT is extinguished when the display is updated.

REMOTE is displayed when the voltmeter is under remote control.

POWER

A push for ON - push for OFF switch for applying mains power to the voltmeter.



Polarity and Overload Display

± Indicated polarity is that of the red lead with respect to the black.

Overload symbol flashes and the display shows 19999 for inputs which exceed 19999.

Display

Numericals displayed by cold cathode tubes with integral decimal points. Decimal point positioning is automatic.

CONTROL

Two mutually exclusive push-button switches for selecting

LOCAL: For control of the voltmeter from the front panel controls. When a Fan Out Unit is fitted and REMOTE is electrically commanded, LOCAL is overridden, REMOTE is displayed and the only effective front panel control is POWER.

REMOTE: For control of the voltmeter by remote electric commands via the Fan Out Unit. When REMOTE is selected REMOTE is displayed.

If no Fan Out Unit is fitted the instrument remains in the LOCAL CONTROL mode.

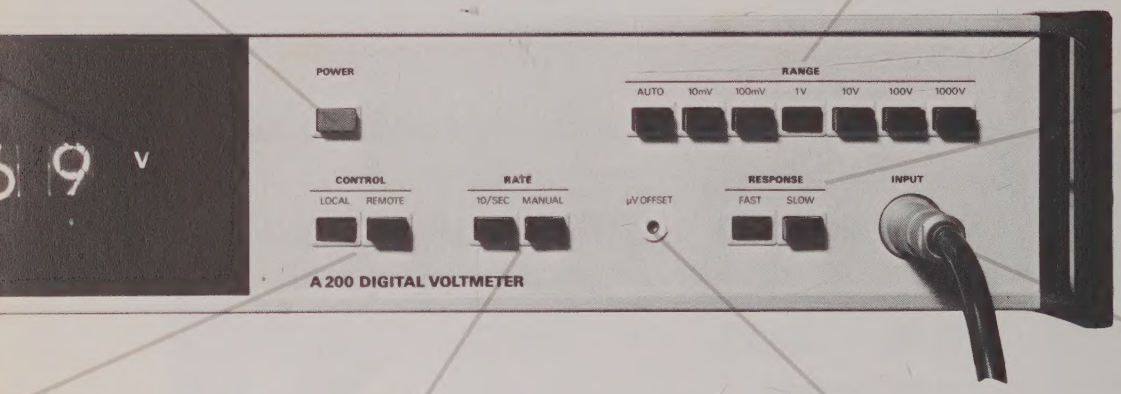
RANGE

Seven mutually exclusive push-button switches for selecting

1) **AUTO**: For automatic selection of the optimum range.

2) **10mV, 100mV, 1V, 10V, 100V or 1000V DC ranges.**

If two or more buttons are pressed the least sensitive range is selected. If no buttons are pressed the 1000V range is selected.



RATE

Two mutually exclusive push-button switches for selecting

10/SEC: For automatic updating of the display every 100ms.

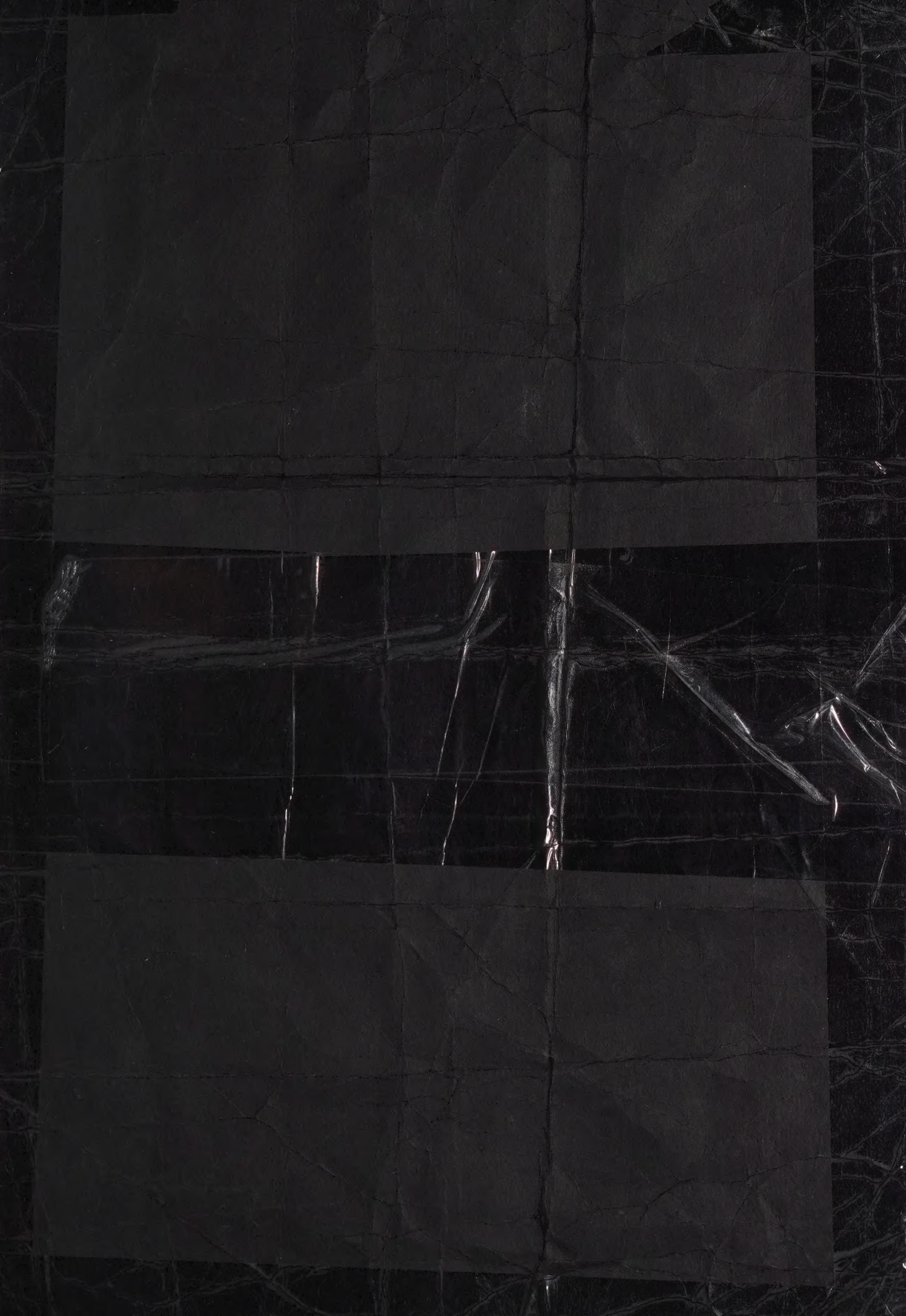
MANUAL: Initial depression of this button releases the 10/SEC button and initiates the display of a measurement. Each subsequent depression commands the display of a new measurement.

If SLOW RESPONSE is selected the display is updated 1 second after pressing the button. (During this time WAIT is displayed).

Both of these controls are effective even if REMOTE has been selected on the front panel CONTROL buttons, provided REMOTE has not been externally commanded via a Fan Out Unit.

μV OFFSET

A potentiometer for 'backing-off' external offsets (e.g. thermal emf's from relay contacts) when making measurements on the 10mV range. Provides not less than ± 10μV offset capability.



Indicator

Displays units (mV, V and kΩ), WAIT and REMOTE

WAIT is displayed to indicate that the display has not been updated with the result of the latest measurement.

1) When a MANUAL sample has been initiated whilst the voltmeter is in the SLOW RESPONSE mode.

2) When a MANUAL sample has been initiated whilst the voltmeter is in the AC mode.

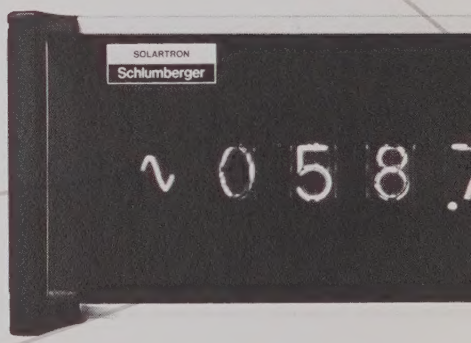
3) When the voltmeter is AUTO ranging with SLOW RESPONSE DC or Ω (ohms) measurements or with AC measurements.

WAIT is extinguished when the display is updated.

REMOTE is displayed when the voltmeter is under remote control.

POWER

A push for ON - push for OFF switch for applying mains power to the voltmeter.



Polarity and Overload Display

± Indicated polarity is that of the red lead with respect to the black.

∿ Sine wave symbol displayed in the AC mode.

Overload symbol flashes and the display shows 19999 for inputs which exceed 19999.

Display

Numericals displayed by cold cathode tubes with integral decimal points. Decimal point positioning is automatic.

CONTROL

Two mutually exclusive push-button switches for selecting

LOCAL: For control of the voltmeter from the front panel controls. When a Fan Out Unit is fitted and REMOTE is electrically commanded, LOCAL is overridden, REMOTE is displayed and the only effective front panel control is POWER.

REMOTE: For control of the voltmeter by remote electric commands via the Fan Out Unit. When REMOTE is selected REMOTE is displayed.

If no Fan Out Unit is fitted the instrument remains in the LOCAL CONTROL mode.

MODE

Three mutually exclusive push-button switches for selecting either DC, AC or Ω (ohms) measurements. As a safety precaution, if two, all or none of the buttons are pressed DC MODE is selected. Also, if all the buttons are released DC MODE is selected.

RANGE

Seven mutually exclusive push-button switches for selecting

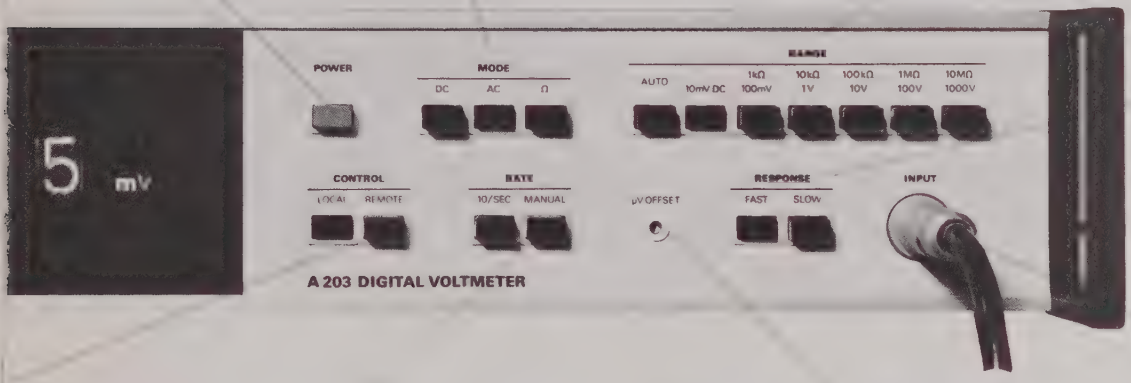
1) **AUTO:** For automatic selection of the optimum range.

2) **10mV, 100mV, 1V, 10V, 100V or 1000V DC ranges.**

3) **100mV, 1V, 10V, 100V or 1000V AC ranges.**
The 10mV DC button selects the 100mV range during AC measurement.

4) **1kΩ, 10kΩ, 100kΩ, 1MΩ or 10MΩ resistance ranges.** The 10mV DC button selects the 1kΩ range during Ω (ohms) measurement.

If two or more buttons are pressed the least sensitive range is selected. If no buttons are pressed the 1000V or 10MΩ range is selected.



RATE

Two mutually exclusive push-button switches for selecting

10/SEC: For automatic updating of the display every 100ms.

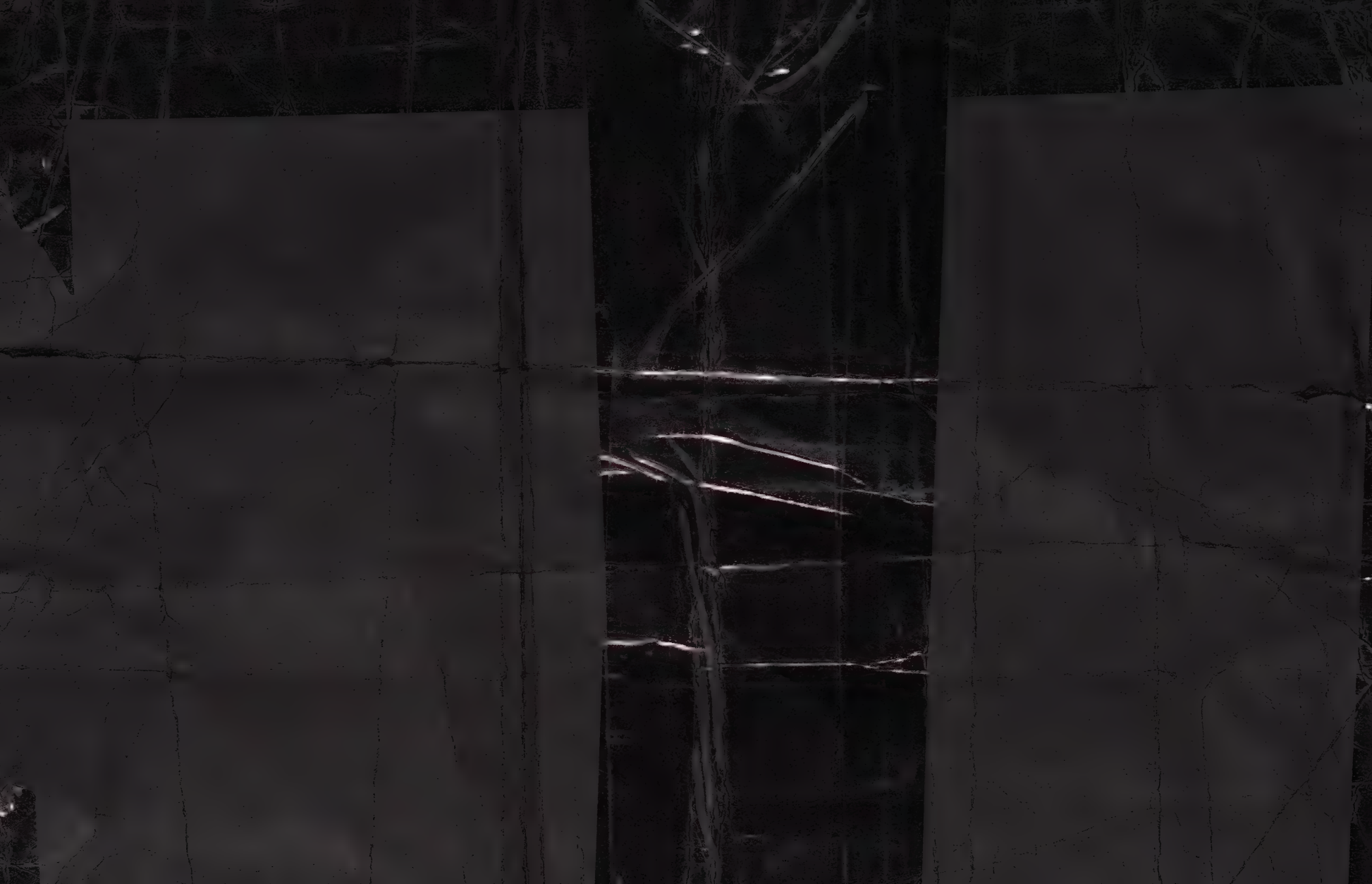
MANUAL: Initial depression of this button releases the 10/SEC button and initiates the display of a measurement. Each subsequent depression commands the display of a new measurement.

If AC and/or SLOW RESPONSE is selected the display is updated 1 second after pressing the button. (During this time WAIT is displayed).

Both of these controls are effective even if REMOTE has been selected on the front panel CONTROL buttons, provided REMOTE has not been externally commanded via a Fan Out Unit.

μV OFFSET

A potentiometer for 'backing-off' external offsets (e.g. thermal emf's from relay contacts) when making measurements on the 10mV range. Provides not less than ± 10μV offset capability.



SECTION 1 Controls

A200

RESPONSE

Two mutually exclusive push-button switches for selecting

FAST: For unfiltered DC measurements.

SLOW: For filtered DC measurements. An active low pass filter provides an additional 30dB series mode rejection at 50Hz increasing at 6dB/octave (20dB/decade).

INPUT

'Snap-in' connector to which the signal is applied via a screened cable.

To remove the connector, pull the skirt of the connector and not the cable.

RESPONSE

Two mutually exclusive push-button switches for selecting

FAST: 1) For unfiltered DC measurements.

2) For unfiltered resistance measurements.

3) For measurement of AC signals with frequency components $\geqslant$ 100Hz. If 10/SEC RATE is selected wait 1 second after application of the signal before reading the display.

SLOW: 1) For filtered DC measurements. An active low pass filter provides an additional 30dB series mode rejection at 50Hz increasing at 6dB/octave (20dB/decade).

2) For filtered resistance measurements using the same filter as for dc. Not recommended when AUTO ranging for resistances above 50kΩ.

3) For extended AC low frequency performance (down to 20Hz). If 10/SEC RATE is selected wait 5 seconds after application of the signal before reading the display. If MANUAL is selected wait 4 seconds after application of the signal before pressing the button.

When AC and AUTO range is selected SLOW RESPONSE is inhibited and the voltmeter reverts to FAST RESPONSE.

INPUT

'Snap-in' connector to which the signal is applied via a screened cable.

To remove the connector, pull the skirt of the connector and not the cable.

A203

(ac mean sensing)

A205

(rms sensing)

Indicator

Displays units (mV or V), WAIT and REMOTE.

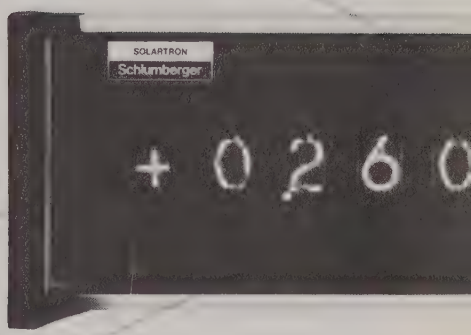
WAIT is displayed to indicate that the display has not been updated with the result of the latest measurement when a MANUAL sample has been initiated whilst the voltmeter is in the SLOW RESPONSE mode.

WAIT is extinguished when the display is updated.

REMOTE is displayed when the voltmeter is under remote control.

POWER

A push for ON - push for OFF switch for applying mains power to the voltmeter.



Polarity and Overload Display

$\pm$ Indicated polarity is that of the red lead with respect to the black.

Overload symbol flashes and the display shows 19999 for inputs which exceed 19999.

Display

Numericals displayed by cold cathode tubes with integral decimal points. Decimal point positioning is automatic.

CONTROL

Two mutually exclusive push-button switches for selecting

LOCAL: For control of the voltmeter from the front panel controls. When a Fan Out Unit is fitted and REMOTE is electrically commanded, LOCAL is overridden, REMOTE is displayed and the only effective front panel control is POWER.

REMOTE: For control of the voltmeter by remote electric commands via the Fan Out Unit. When REMOTE is selected REMOTE is displayed.

If no Fan Out Unit is fitted the instrument remains in the LOCAL CONTROL mode.

A227 only;
AUTO RANGE
button here

RANGE

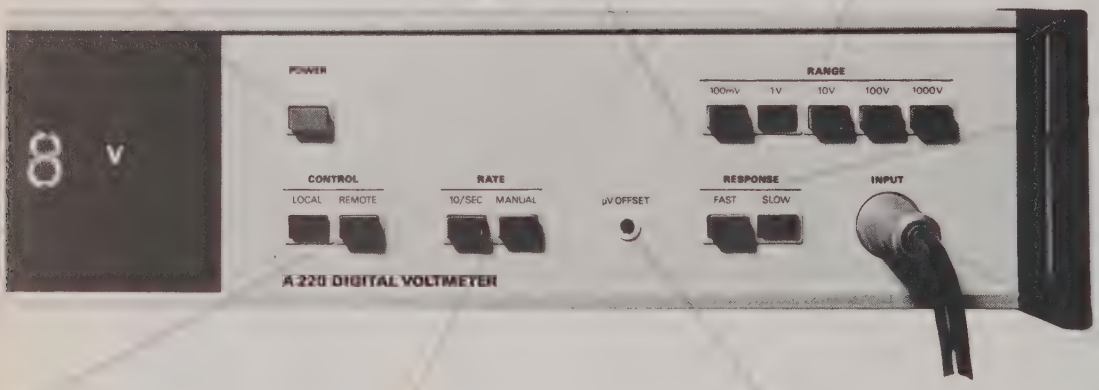
A220
Five mutually exclusive push button switches for selecting the **100mV,1V,10V,100V or 1000V DC ranges.**

A227
Six mutually exclusive push button switches for selecting:

1) AUTO: For automatic selection of optimum range.

2) 100mV,1V,10V,100V or 1000V DC ranges.

On both the A220 and A227, if two or more buttons are pressed the least sensitive range is selected.
If no buttons are pressed the 1000V range is selected.



RATE

Two mutually exclusive push-button switches for selecting

10/SEC: For automatic updating of the display every 100ms.

MANUAL: Initial depression of this button releases the 10/SEC button and initiates the display of a measurement. Each subsequent depression commands the display of a new measurement.

If SLOW RESPONSE is selected the display is updated 1 second after pressing the button. (During this time WAIT is displayed).

Both of these controls are effective even if REMOTE has been selected on the front panel CONTROL buttons, provided REMOTE has not been externally commanded via a Fan Out Unit.

μV OFFSET

A potentiometer for 'backing-off' external offsets (e.g. thermal emf's from relay contacts) when making measurements on the 100mV range. Provides not less than $\pm$ 100μV offset capability.

A220

A227

RESPONSE

Two mutually exclusive push-button switches for selecting

FAST: For unfiltered DC measurements.

SLOW: For filtered DC measurements. An active low pass filter provides an additional 30dB series mode rejection at 50Hz increasing at 6dB/octave (20dB/decade).

INPUT

'Snap-in' connector to which the signal is applied via a screened cable.

To remove the connector, pull the skirt of the connector and not the cable.

Indicator

Displays units (mV, V and kΩ), WAIT and REMOTE.

WAIT is displayed to indicate that the display has not been updated with the result of the latest measurement.

1) When a MANUAL sample has been initiated whilst the voltmeter is in the SLOW RESPONSE mode.

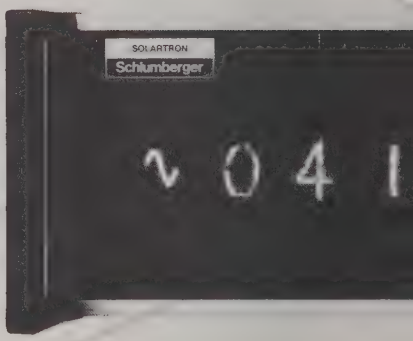
2) When a MANUAL sample has been initiated whilst the voltmeter is in the AC mode.

WAIT is extinguished when the display is updated.

REMOTE is displayed when the voltmeter is under remote control.

POWER

A push for ON - push for OFF switch for applying mains power to the voltmeter.



Polarity and Overload Display

± Indicated polarity is that of the red lead with respect to the black.

∿ Sine wave symbol displayed in the AC mode.

Overload symbol flashes and the display shows 19999 for inputs which exceed 19999.

Display

Numericals displayed by cold cathode tubes with integral decimal points. Decimal point positioning is automatic.

CONTROL

Two mutually exclusive push-button switches for selecting

LOCAL: For control of the voltmeter from the front panel controls. When a Fan Out Unit is fitted and REMOTE is electrical commanded, LOCAL is overridden, REMOTE is displayed and the only effective front panel control is POWER

REMOTE: For control of the voltmeter by remote electric commands via the Fan Out Uni When REMOTE is selected REMOTE is displayed.

If no Fan Out Unit is fitted the instrument remains in the LOCAL CONTRO mode.

MODE

Three mutually exclusive push-button switches for selecting either DC, AC or Ω (ohms) measurements. As a safety precaution, if two, all or none of the buttons are pressed DC MODE is selected. Also, if all the buttons are released DC MODE is selected.

RANGE

Five mutually exclusive push-button switches for selecting

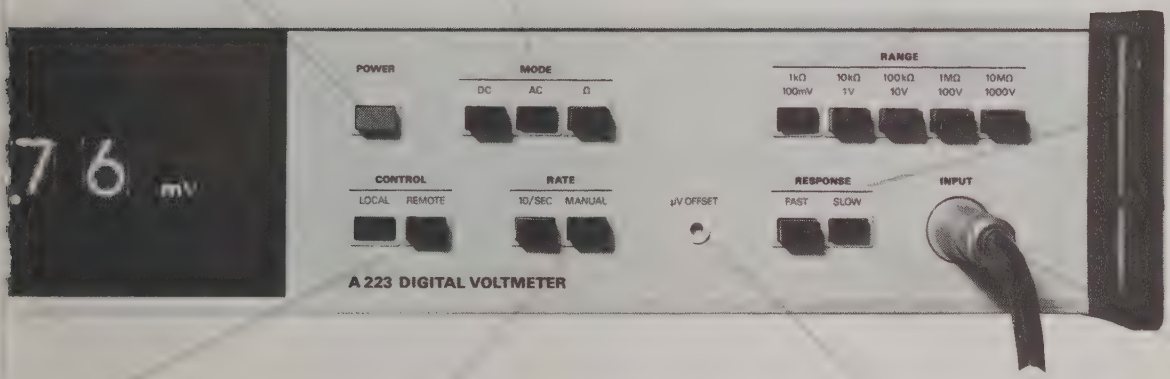
1) **100mV, 1V, 10V, 100V or 1000V DC ranges.**

2) **100mV, 1V, 10V, 100V or 1000V AC ranges.**

3) **1kΩ, 10kΩ, 100kΩ, 1MΩ or 100MΩ resistance ranges.**

If two or more buttons are pressed

If two or more buttons are pressed the least sensitive range is selected. If no buttons are pressed the 1000V or 10MΩ range is selected.



RATE

Two mutually exclusive push-button switches for selecting

10/SEC: For automatic updating of the display every 100ms.

MANUAL: Initial depression of this button releases the 10/SEC button and initiates the display of a measurement. Each subsequent depression commands the display of a new measurement.

If AC and/or SLOW RESPONSE is selected the display is updated 1 second after pressing the button. (During this time WAIT is displayed).

Both of these controls are effective even if REMOTE has been selected on the front panel CONTROL buttons, provided REMOTE has not been externally commanded via a Fan Out Unit.

μV OFFSET

A potentiometer for 'backing-off' external offsets (e.g. thermal emf's from relay contacts) when making measurements on the 100mV range. Provides not less than ± 100μV offset capability.

RESPONSE

Two mutually exclusive push-button switches for selecting

FAST: 1) For unfiltered DC measurements.

2) For unfiltered resistance measurements.

3) For measurement of AC signals with frequency components ⩾ 100Hz. If 10/SEC RATE is selected wait 1 second after application of the signal before reading the display.

SLOW: 1) For filtered DC measurements. An active low pass filter provides an additional 30dB series mode rejection at 50Hz increasing at 6dB/octave (20dB/decade).

2) For filtered resistance measurements using the same filter as for dc. Not recommended when AUTO ranging for resistances above 50kΩ.

3) For extended AC low frequency performance (down to 20Hz). If 10/SEC RATE is selected wait 5 seconds after application of the signal before reading the display. If MANUAL is selected wait 4 seconds after application of the signal before pressing the button.

A223

(ac mean sensing)

A225

(rms sensing)

INPUT

'Snap-in' connector to which the signal is applied via a screened cable.

To remove the connector, pull the skirt of the connector and not the cable.

Rear Input

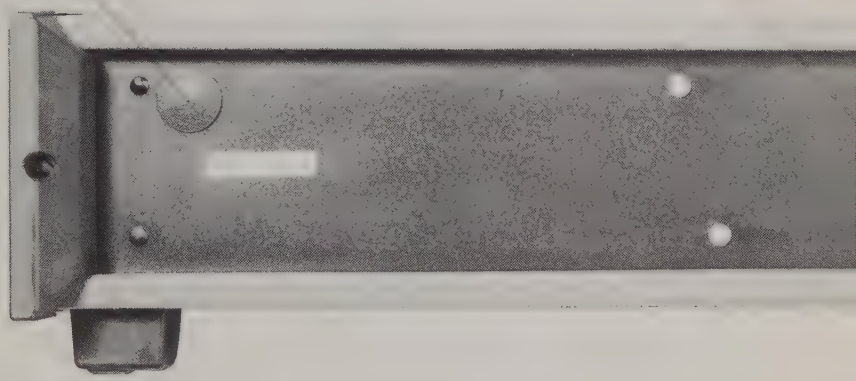
Position where rear input socket can be fitted

Fuse Holder

98 to 128V : 500mA/750mA* SLO-BLO fuse

195 to 255V : 250mA/300mA* SLO-BLO fuse

* As indicated on MAINS SELECTOR PLATES



Rear Panel
[all units]

Mains Selector Switches

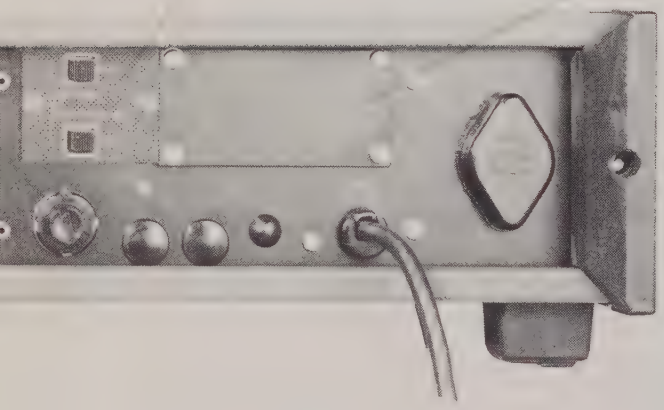
Mains voltage selection is effected by positioning the switches so that the appropriate mains selector plate can be screwed on.

There are four possible ranges of mains input:-

1) 98 - 115V 2) 220 - 255V	50 - 60Hz	Plate 1
3) 110 - 128V 4) 195 - 230V	50 - 60Hz	Plate 2

Blanking Plate

Removed for fan out unit installation.



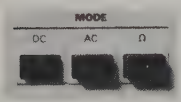
CONTROLS

The push button controls of this series of voltmeters are arranged in six groups in accordance with the six decisions which have to be made for any measurement.

1. POWER

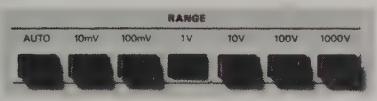
This heavy duty mains switch operates with a push on - push off action. The numerical display is always illuminated whenever the instrument is switched on and no separate warning is required. This is the only button which cannot be remotely controlled, but the voltmeter can, of course, be remotely switched ON and OFF by interruption of the mains supply.

2. MODE



The second group of controls select either DC, AC or Ohms. These buttons are mutually exclusive and pressing any one automatically releases the one previously selected. In the event of a user forcing in more than one of these buttons at the same time (misuse) the voltmeter automatically reverts to the DC mode as a safety precaution. DC only instruments (A200, A220, A227) have no mode switches.

3. RANGE



This row of buttons selects the sensitivity setting. Again, pressing one button releases any previously selected in the group. There is one button for each range and on the A200, A203, A205 and A227 there is also an auto range control. Pressing the AUTO button causes the voltmeter to automatically select the correct range for any input voltage from 1μV to 1000V. Unless there is a particular reason for pre-selecting a fixed range, the use of auto range is recommended - there is no reduction of accuracy, noise rejection or input resistance and in the event of accidental overload, the voltmeter automatically moves to the appropriate range. If more than one range button is pushed, the least sensitive will be selected.

A word of caution: there are more dc ranges than ac or ohms ranges and the 10mV button, although applicable only to dc, could be pressed when AC or Ω has been selected. The voltmeter does not respond to this invalid command and selects instead, the 100mV or 1kΩ range. The units display and decimal point setting will always be correct. As it is normal to think in decimal terms, the legend which identifies each range follows a 1, 10, 100 sequence. However, there is a 99% overrange capability on all ranges. For example, the full scale value of the 1V range is, in fact, 1.9999V. There is no degradation of the performance specification in this upper part of the scale. On voltage measurement however, the maximum recommended input is 1200V dc or 1.2kV peak (850V rms).

4. RESPONSE

As far as dc and ohms measurements are concerned, these controls should be regarded as a luxury and not required in all but the most exceptional circumstances. In general they should be left in the FAST mode. For dc and resistance the SLOW button selects an active low pass filter to reduce the effects of any noise interference. However, because the voltmeter is an integrating type (with mains locked integration on A200, A203 and A205), it inherently rejects mains frequency interference and its harmonics without the filter. SLOW is therefore seldom required. In doubtful cases the effect of the control should be observed: if any change in the reading results from the use of the filter this must be as a result of noise being rejected and SLOW should be chosen in this instance.

The use of a filter introduces long time constants into an otherwise fast acting instrument, and the user should therefore exploit the inherent noise rejecting properties of this instrument and avoid unnecessary use of the filter.

For ac measurement this control has a different purpose. Inherent in the design of an ac measurement system is the compromise between response time and low frequency performance. Therefore, to cater for a wide variety of applications this choice is left to the user. With AC FAST, the response time to 0.1% is 1 second.

If the input signal contains frequency components below 100Hz the reading will fluctuate under the influence of the low frequency. With AC SLOW, the response time is increased to 5 seconds, but accurate readings can be taken on signals which include frequency components down to 20Hz. The upper frequency limit of measurement is unaffected by FAST/SLOW selection.

5. RATE

A feature of these voltmeters is that they operate on a continuous basis, always responding to the applied signal. Whenever they are switched on they are making 10 measurements each second, although the result of every measurement will be displayed only when the 10/SEC button is pressed. When MANUAL is selected the voltmeter still makes 10 measurements each second, but the display is updated only upon pressing the button.

As an added precaution, the auto range circuitry continues to protect the instrument when MANUAL and AUTO have been selected. Even though the display retains the value applicable when the last sample was called for, in this mode of operation the instrument may in fact have moved to a different range under the influence of a change in the input signal. However, the information on the display still remains applicable to the last command measurement.

6. CONTROL

As indicated by the legend these controls affect the changeover from manual (front panel) to remote control. When LOCAL is selected the REMOTE button is released and any remote electrical commands (except a call for REMOTE) are ignored.

The LOCAL/REMOTE buttons are fitted regardless of whether or not Fan-Out Unit A204 has been installed. If there is no fan-out unit and the REMOTE button is operated, local control is retained. With a fan-out unit, when REMOTE is selected control of MODE (DC, AC and Ω), RANGE (including AUTO range) and RESPONSE (FAST/SLOW) is possible only by external electrical commands via the fan-out unit. Other than POWER the only buttons still operative are those for RATE so that front panel control is still available to command either 10/SEC or single sample. In addition, with 10/SEC released, a measurement may be remotely initiated by electrical pulse or contact closure.

A feature made available by the CONTROL switches is that users can remotely command both repetitive or single sample. This is achieved in the following way:-

Select REMOTE and 10/SEC by means of the front panel switches.

For "single shot" sample call REMOTE electrically via the fan-out and initiate each sample by either contact closure or pulse application via the fan-out unit.

For 10/SEC sampling do not electrically command REMOTE.

In both cases control of the remaining functions is by remote command via the fan-out unit.

Front Panel Lock-Out

Not apparent from the front panel is an extra facility known as Front Panel Lock-Out. Under the control of an external electrical command (command REMOTE) applied via Fan-Out Unit A204, the action of all front panel controls can be inhibited with the exception of POWER. In this condition all control must be by electrical command and the LOCAL button cannot be used to regain manual control. The user is reminded of this condition by the word REMOTE being displayed.

This feature prevents unauthorised use when the voltmeter is committed within a system or, with suitable programming of the REMOTE command, enables a test sequence to include both automatic and operator control.

INPUT CONNECTOR

The input connector simply pushes into the front panel socket with a "snap-in" action. This cannot be released by pulling on the cable, but separation occurs only when the skirt of the connector is pulled away from the panel.

The "snap-in" connector has been chosen to permit the use of a long input lead which may be required when the voltmeter is rack mounted. Experience with push-on 4mm connectors has shown that they tend to fall off under the weight of a long lead.

The skirt of the chosen connector acts as an isothermal chamber preventing temperature differentials which would give rise to errors caused by thermal emf's. The standard input lead provides connection for signal high (red) and signal low (black). It will be seen that the connector contains five pins and users wishing to use a three terminal driven guard, input configuration should use input lead EX 3183 available as an optional extra. (A guide to three terminal measurement in "noisy" conditions can be obtained from the Solartron publication "Digital Voltmeters and Interference" which is free on request). This same lead is also used for a 4 terminal ohms measurement which is described later in this manual. The input to the voltmeter is completely isolated from earth and from all of the programming inputs and digital outputs.

Rear Input

This is fitted only on request and is wired in parallel with the normal front input. The input capacitance is increased by 80pF. The back panel includes a cut-out for the later addition of a rear input, and users installing their own rear connector are reminded that the use of p.t.f.e. coated wire is necessary to maintain the isolation characteristics.

μV OFFSET

A200, A203 and A205 include a sophisticated chopper input amplifier to maintain very high integrity μV measurement. The stability of the input stage is such that, provided 90 minutes initial warm up is allowed, the drift with time is less than 1μV per week on the 10mV range; initial warm up on all other range is 60 minutes.

External conductors, however, may introduce thermal errors and the μV OFFSET control can be used to offset such effects. The range of offset is ± 15μV.

DISPLAY

The display area is covered by a tinted screen laminated with a circularly polarised membrane to inhibit stray light or reflected light from the indicator tubes. The front surface is lightly frosted to eliminate surface reflection from overhead lights or light coloured garments worn by the user. Very slight de-focusing results from this frosting.

The display information is updated either ten times per second or on manual command as described earlier.

From left to right the information is:-

a) ± **Automatic polarity indication.** The polarity is that of the red lead with respect to the black.

b) ∿ This sign is displayed when AC MODE is selected.

c) Overrange indication is given by a flashing symbol when the input exceeds 19999. The user is not required to remember the full scale of the instrument.

d) **Numerical Indication.** Cold cathode neon number tubes, which have been proved to have extremely long life, are used to present the result of measurement.

e) **Decimal Point.** This is positioned automatically in conjunction with the units display.

f) **Units.** V, mV and kΩ. Display of the units is automatic and appropriate to the sensitivity and mode. Units, decimal point and numerical information are updated only as a result of digitise command as directed by the RATE control.

g) **Wait.** When the user selects a slow mode of operation, for example SLOW and AUTO range, an appreciable period of time may elapse before the new measurement is complete. During this time the result of the previous measurement is retained by the display. As a precaution against the wrong value being noted the legend WAIT lights up and is only extinguished when the new result is displayed.

h) **Remote.** Indication that the instrument is under either remote control or front panel lock-out. Only applicable when fan-out A204 is fitted.

Rack Mounting

The overall dimensions conform to international standards for rack mounting. The instrument can be rack mounted within its case with no additional protection required. Users who wish to remove the top, bottom and side covers can do so by undoing the two screws which secure the side covers and sliding out all the covers starting with the sides. For rack mounting the combination handle/ears should be substituted for the normal handles. These combination rack mounting handles are supplied in the accessory pack with each voltmeter.

SECTION 2 Technical Specification

DC RANGES

Range	Sensitivity	Full Scale	Input Resistance
10mV*	1μV	19.999mV	> 1000MΩ
100mV	10μV	199.99mV	> 10000MΩ
1V	100μV	1.9999V	> 10000MΩ
10V	1mV	19.999V	> 10000MΩ
100V	10mV	199.99V	10MΩ ± 0.1%
1000V	100mV	1200.0V**	10MΩ ± 0.1%

* A200/A203/A205 only.

** 1000V range: Although full scale remains 1999.9V it is advisable not to exceed the given value.

AC RANGES (A203, A205, A223, A225)

Range	Sensitivity	Full Scale	Input Impedance*
100mV	10μV	199.99mV	10MΩ/< 100pF
1V	100μV	1.9999V	10MΩ/< 100pF
10V	1mV	19.999V	1MΩ/< 50pF
100V	10mV	199.99V	1MΩ/< 50pF
1000V	100mV	1000V**	1MΩ/< 50pF

* Input Capacitance excludes that presented by the input cable.

** 1000V Range: Although full scale remains 1999.9V 1.2kV peak (850V rms) must not be exceeded.

OHMS RANGES (A203, A205, A223, A225)

Range	Sensitivity	Full Scale	Test Current
1kΩ	100mΩ	1.9999kΩ	600μA
10kΩ	1Ω	19.999kΩ	600μA
100kΩ	10Ω	199.99kΩ	60μA
1MΩ	100Ω	1999.9kΩ	0.6μA
10MΩ	1kΩ	19999.kΩ	0.6μA

REMOTE RANGE: The remote selection of any range may be commanded via optional Fan-Out unit A204.

OVERLOAD: An overload symbol flashes and the display shows 19999 for inputs which exceed 19999.

AUTO RANGE: Auto is available on A200, A203, A205 and A227 only. Operates on all ranges.

AC SCALING:

(A203, A223) The instrument senses the mean value of the ac component and displays the rms value - assuming a sine wave signal.

(A205, A225) The instrument senses the true rms value of the ac component regardless of waveshape.

SHORT TERM ACCURACY

For 24 hours and within ± 1°C of temperature stability. Resolution and linearity errors are included.

DC RANGES

Range	A200/A203/A205		A220/A223/A225/A227	
	of reading	of full scale	of reading	of full scale
10mV	± 0.01%	± 0.005%	–	–
100mV, 1V, 10V, 100V and 1000V	± 0.005%	± 0.005%	± 0.01%	± 0.005%

LONG TERM ACCURACY

For 90 days ± 5°C. Assumes occasional front panel zero adjustment.

Unless otherwise stated, full scale = 20000.

DC RANGES

Range	A200/A203/A205		A220/A223/A225/A227	
	of reading	of full scale	of reading	of full scale
10mV	± 0.02%	± 0.005%	–	–
100mV	± 0.02%	± 0.005%	± 0.02%	± 0.01%
1V	± 0.02%	± 0.005%	± 0.02%	± 0.005%
10V	± 0.02%	± 0.005%	± 0.02%	± 0.005%
100V	± 0.025%	± 0.005%	± 0.05%	± 0.005%
1000V	± 0.025%	± 0.005%	± 0.05%	± 0.005%

AC RANGES 40Hz to 20kHz (mean sensing)

Range	A203		A223	
	of reading	of full scale	of reading	of full scale
100mV	± 0.05%	± 0.03%	± 0.05%	± 0.03%
1V	± 0.05%	± 0.03%	± 0.05%	± 0.03%
10V	± 0.1%	± 0.03%	± 0.1%	± 0.03%
100V	± 0.1%	± 0.03%	± 0.1%	± 0.03%
1000V	± 0.1%	± 0.06%	± 0.1%	± 0.06%

AC RANGES 20Hz to 100kHz (mean sensing)

Range	A203		A223	
	of reading	of full scale	of reading	of full scale
100mV	1%	± 0.03%	1%	± 0.03%
1V	1%	± 0.03%	1%	± 0.03%
10V	1%	± 0.03%	1%	± 0.03%
100V	1%	± 0.03%	1%	± 0.03%
1000V	1%	± 0.06%	1%	± 0.06%

AC RANGES 40Hz to 10kHz (A205/A225) (sine wave inputs between 1% and 100% of full scale)

Range	of reading	of full scale
100mV	± 0.1%	± 0.1%
1V	± 0.1%	± 0.1%
10V	± 0.1%	± 0.1%
100V	± 0.1%	± 0.1%
1000V	± 0.1%	± 0.1%

AC RANGES 10Hz to 100kHz (A205/A225) (sine wave inputs between 1% and 100% of full scale)

Range	of reading	of full scale
100mV	± 0.2%	± 1.0%
1V	± 0.2%	± 1.0%
10V	± 0.2%	± 1.0%
100V	± 0.2%	± 1.0%
1000V	± 0.2%	± 1.0%

RESISTANCE RANGES

Range	A203/A205		A223/A225	
	of reading	of full scale	of reading	of full scale
1kΩ	+ 0.01%	+ 0.01%	+ 0.01%	± 0.01
10kΩ	+ 0.01%	+ 0.01%	+ 0.01%	± 0.01
100kΩ	+ 0.01%	+ 0.01%	+ 0.01%	± 0.01
1MΩ	+ 0.05%	+ 0.01%	+ 0.05%	+ 0.01
10MΩ	+ 0.5%	+ 0.02%	+ 0.5%	± 0.0

TEMPERATURE EFFECTS

DC RANGES

	A200/A203/A205	A220/A223/A225/A227
Zero Drift 0 - 50°C :	± 0.2μV per °C	± 1μV per °C

Coefficient of Reading 0 - 50°C

Range	A200/A203/A205	A220/A223/A225/A227
10mV	< ± 0.002% per °C	–
100mV	< ± 0.002% per °C	< ± 0.002% per °C
1V	< ± 0.002% per °C	< ± 0.002% per °C
10V	< ± 0.002% per °C	< ± 0.002% per °C
100V	< ± 0.0025% per °C	< ± 0.003% per °C
1000V	< ± 0.0025% per °C	< ± 0.003% per °C

AC RANGES

Coefficient of Reading 0 - 50°C. 20Hz - 100kHz

Range	A203	A223
100mV	< ± 0.0025% per °C	< ± 0.0025% per °C
1V	< ± 0.0025% per °C	< ± 0.0025% per °C
10V	< ± 0.015% per °C	< ± 0.015% per °C
100V	< ± 0.015% per °C	< ± 0.015% per °C
1000V	< ± 0.015% per °C	< ± 0.015% per °C

Coefficient of reading 0 - 50°C. 10Hz to 100kHz A205/A225

All ranges

± 0.015% of reading

± 0.001% of full scale

RESISTANCE RANGES

Zero Drift 0 - 50°C

Range	A203/A205	A223/A225
1kΩ	0.001% of full scale per °C	0.001% of full scale per °C
10kΩ	0.0001% of full scale per °C	0.0001% of full scale per °C
100kΩ	0.0001% of full scale per °C	0.0001% of full scale per °C
1MΩ	0.001% of full scale per °C	0.001% of full scale per °C
10MΩ	0.001% of full scale per °C	0.001% of full scale per °C

Coefficient of Reading 0 - 50°C

Range	A203/A205	A223/A225
1kΩ	< ± 0.002% per °C	< ± 0.004% per °C
10kΩ	< ± 0.002% per °C	< ± 0.004% per °C
100kΩ	< ± 0.002% per °C	< ± 0.004% per °C
1MΩ	< ± 0.002% per °C	< ± 0.004% per °C
10MΩ	< ± 0.002% per °C	< ± 0.004% per °C

CREST FACTOR A205/A225 only

4:1 at full scale up to 20kHz

INPUT CHARACTERISTICS

Input voltage should not exceed 100V whilst changing mode.

DC RANGES

Input Current: $< 10^{-10}$ A

Overload

10mV, 100mV, 1V, 10V Ranges

Max. permitted input: 200V continuous (1200V for up to 200ms)

100V, 1000V Ranges

Max. permitted input: 1200V

Input resistance: 10MΩ ± 0.1%

AC RANGES

Overload

100mV, 1V Ranges

Max. permitted input: 300V peak (1200V peak for up to 2s) Note. On models A205 and A225 the input voltage/frequency must not exceed 6 x 10^6 VHz

10V, 100V, 1000V Ranges

Max. permitted input: 1.2kV peak (850V rms)

RESISTANCE RANGES

Overload

All ranges

Max. permitted input 300V. peak

ISOLATION IMPEDANCE

Guard to Chassis: $> 10^{10}\Omega$ and < 500pF

RESPONSE TIMES

Auto Range Response Time

DC FAST: Shall have selected the correct range within 0.7s.

DC SLOW: Shall have selected the correct range within 6s.

AC FAST: Shall have selected the correct range within 6s, A203/A223 or 7s, A205.

AC SLOW: Not available. Voltmeter reverts to AC, FAST AUTO range.

Ω FAST: Shall have selected the correct range within 0.7s for resistances $\leq 1M\Omega$

Ω SLOW: As DC SLOW for values $<50k\Omega$
Not recommended for values $>50k\Omega$

INTERFERENCE REJECTION – SERIES MODE

The ratio of the peak interference at the input terminals to one digit reading error. These figures apply providing that the applied signal plus the noise does not exceed 120% of full scale, on each range (but note the maximum permissible input on the 1000V range).

DC FAST

A200/A203/A205: $>$ 70dB at mains frequency (Nominal 50Hz ± 2%)

A220/A223/A225/A227: $>$ 36dB at 50Hz ± 1%

DC SLOW

A low pass active filter increases the above figures by 30dB at 50Hz increasing at 6dB/Octave.

INTERFERENCE REJECTION – COMMON MODE

The ratio of the peak interference, applied between signal source and instrument ground (chassis), to the reading error, when there is 1kΩ unbalance between the high and low signal paths.

The maximum common mode voltage must not exceed 500V dc or peak ac.

DC RANGES With Guard connected to Lo in the standard input cable (2 terminal measurement):

	A200/A203/A205	A220/A223/A225/A227
DC	> 140dB	> 140dB
50Hz FAST	> 145dB	> 110dB
50Hz SLOW	> 174dB	> 155dB

AC RANGES With guard connected to Lo in the standard input cable (2 terminal measurement)

	A203/A205	A223/A225
DC	> 140dB	> 140dB
50Hz FAST	> 40dB	> 40dB
50Hz SLOW	> 40dB	> 40dB

DC RANGES With Guard connected to the source of common mode (3 terminal measurement).

	A200/A203/A205	A220/A223/A225/A227
DC	> 150dB	> 150dB
50Hz FAST	> 160dB	> 125dB
50Hz SLOW	> 174dB	> 155dB

AC RANGES With Guard connected to the source of common mode (3 terminal measurement).

	A203/A205	A223/A225
DC	> 150dB	> 150dB
50Hz FAST	> 60dB	> 60dB
50Hz SLOW	> 60dB	> 60dB

TEMPERATURE RANGE

Operation: This specification applies for operation in the ambient ranges 0 - 40°C (A220/A223/A225/A227) and 0 - 55°C (A200/A203/A205)

Storage: The instrument can be stored at ambients between -30°C and +70°C.

MAINS SUPPLY

This specification relates to supplies of 117/234V + 10% -15%, 50Hz or 60Hz. Modification is necessary to achieve full interference rejection at 60Hz.

Consumption: 40VA.

Fan Out Unit A204

Outputs: TTL Compatible.
High (Logic 1) + 2.4V to + 6V from a 6kΩ source
Low (Logic 0) – 0.5V to + 0.5V at 10mA 'sink'.

Inputs: TTL Compatible.
High (Logic 1) + 2.4V to + 6V or open circuit.
Low (Logic 0) – 0.5V to + 0.5V at 5mA 'sink'.

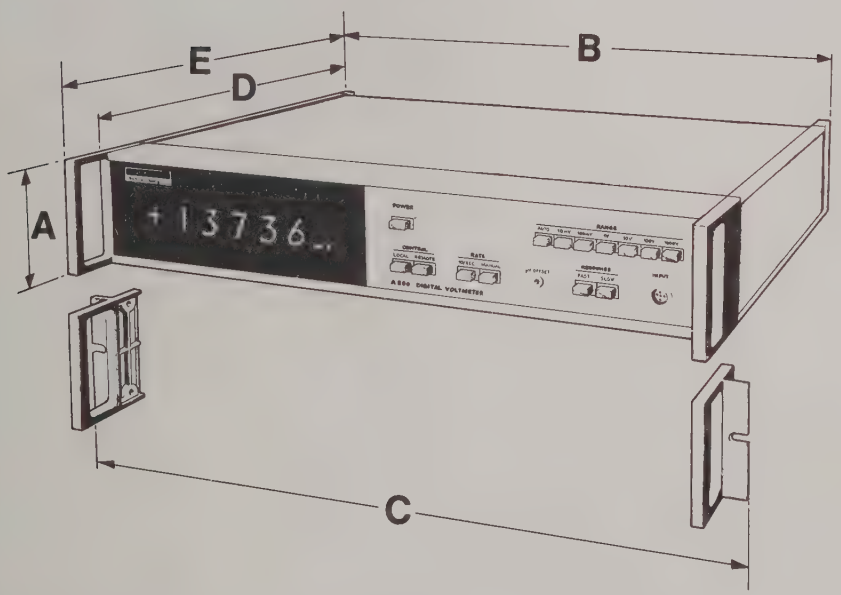
Pulse Sample

Pulse Amplitude: +3V to +8V

Duration: $> 10\mu s$.

Input Impedance: $> 10k\Omega$

DIMENSIONS



A = 88mm (3.46in)
B = 442mm (17.40in)
C = 482mm (18.98in)
D = 322.58mm (12.70in) Without side covers.
E = 362.58mm (14.28in) Without side covers.

Weight

7kg (15½lb) (Dependent upon model)

ACCESSORIES

Each voltmeter is supplied with the following:-

	Solartron Part No.
Signal Input Lead with 4mm Plug Terminations	A2000168
Test Prod (Red)	351901020
Test Prod (Black)	351901010
Croc. Clip (Red)	355900670
Croc. Clip (Black)	355900660
Fuse 500mA SLO–BLO (2 off)	306103060
Fuse 250mA SLO–BLO (2 off)	306103050
Handle, Rack Mounting	A2000111

Each fan out unit is supplied with the following:-

50 Way Plug (BICC MS50 RN–BR118) (1 off)	354002340
Pins (BICC RM20M – 12 – D29) (50 off)	354001610

SECTION 3 Operating Instructions

PRELIMINARY ADJUSTMENTS

Check that the instrument is set to operate from the local mains supply.

Check that the correct fuse is fitted.

250mA/300mA* SLO-BLO for mains voltage between 195V and 255V
500mA/750mA* SLO-BLO for mains voltage between 98V and 128V

Connect a suitable plug to the mains lead:-

BROWN	-	LINE
BLUE	-	NEUTRAL
GREEN/YELLOW	-	EARTH

* As indicated on Mains Selector Plate

DC VOLTAGE MEASUREMENT

Although the maximum dc input voltages that may safely be applied to the instrument are:

i) 1200V on the 1000V and 100V ranges

ii) 200V on the 10V, 1V, 100mV and 10mV ranges

the 10V, 1V, 100mV and 10mV ranges will withstand 1200V for up to 200ms. Thus, for AUTO range purposes, the range of input voltages can be from 0 to 1200V.

1. Switch POWER on.

2. Select LOCAL or REMOTE. If the instrument is fitted with a fan out unit and REMOTE is selected see the section of this manual which covers remote operation for a list and description of the remote control facilities. If LOCAL is selected, read on from step 3.

3. Choose an appropriate range or AUTO range.

4. If the instrument is an A203 or A223 press the DC MODE push-button.

5. Connect the input lead to the unknown voltage source, red to signal high and black to signal low.

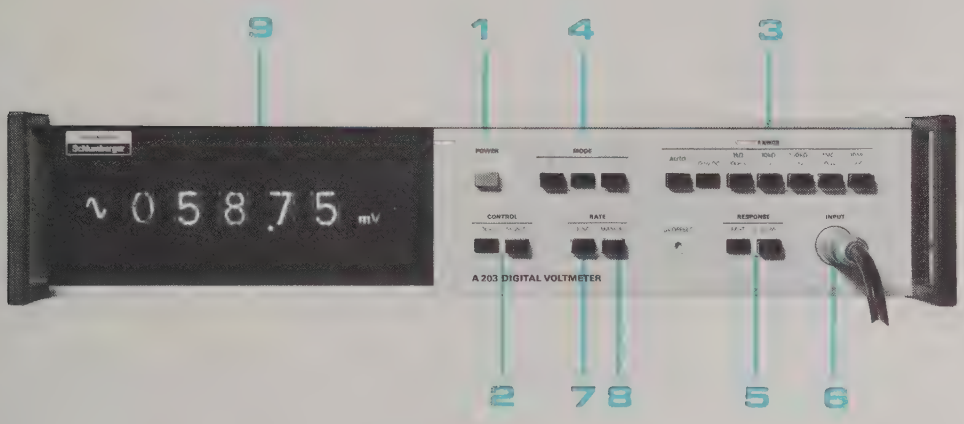
6. Press the 10/SEC push-button for repetitive measurement or, alternatively,

7. Press the MANUAL push-button for 'single shot' measurement.

8. Select SLOW or FAST RESPONSE for filtered or unfiltered measurement. If in doubt about the necessity to use the filter, press the SLOW button and if no change in the reading occurs then the filter is unnecessary. If there is a difference between the results of the filtered and unfiltered measurement, then the result with the filter is correct.

9. Read the voltage from the display and, if necessary, downrange to obtain greater sensitivity. The indicated polarity is that of the red lead with respect to the black.

AC VOLTAGE MEASUREMENT



Although the maximum ac voltages which may safely be applied to the instrument are:-

i) 1200V peak (846V rms) on the 100V and 10V ranges
ii) 300V peak on the 1V and 100mV ranges

} (or less than 6 x 10^6VHz on A205 and A225).

the 1V and 100mV ranges will withstand 1200V peak for up to 2 seconds. Thus, for AUTO range purposes the range of input voltage can be 0 to 1200V peak.

1. Switch POWER on.

2. Select LOCAL or REMOTE. If a fan out unit is fitted and REMOTE is selected, see the section of this manual which covers remote operation for a list and description of the remote control facilities. If LOCAL is selected read on from step 3.

3. Choose an appropriate range or AUTO range.

4. Press the AC MODE push-button.

5. Select SLOW or FAST RESPONSE depending on the low frequency limit required: SLOW for frequencies down to 20Hz or FAST for frequencies down to 100Hz. SLOW is not available in conjunction with AUTO. As soon as the voltmeter detects that SLOW and AUTO range have been selected it automatically goes to the FAST RESPONSE mode.

6. Connect the input lead to the unknown voltage source, red to signal high and black to signal low.

7. Press the 10/SEC push-button for repetitive measurement or, alternatively.

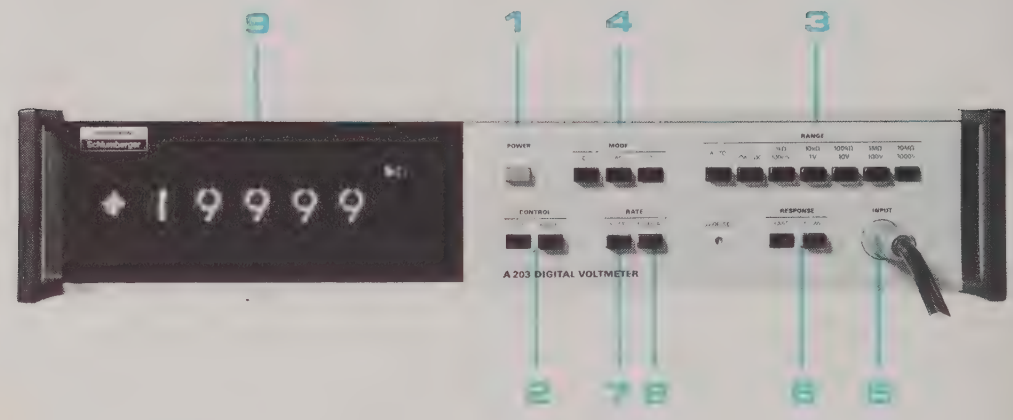
8. Press the MANUAL push-button for 'single shot' measurement.

   Note: If 10/SEC is selected the instrument displays the result of measurement ten times a second and it will be necessary to wait 1 second (FAST) or 5 seconds (SLOW), after connecting the signal to the input, for an accurate result.

   If MANUAL is selected the display is updated 1 second after pressing the button. During this time WAIT is displayed. For an accurate result if SLOW is selected, the input signal must be connected for 4 seconds before the button is pressed.

9. Read the voltage from the display and, if necessary, downrange to obtain greater sensitivity. The displayed reading is rms voltage assuming a sine wave input, using an A203 or A223. The A205 or A225 will read rms regardless of waveshape (within the limits of the specification).

RESISTANCE MEASUREMENT



1. Switch POWER on.

2. Select LOCAL or REMOTE. If a fan out unit is fitted and REMOTE is selected see the section of this manual which covers remote operation, for a list and description of the remote control facilities. If LOCAL is selected read on from step 3.

3. Choose an appropriate range or AUTO range.

4. Press the Ω MODE button.

5. Connect the input lead to the unknown resistance.

6. Press the FAST RESPONSE button. Although SLOW RESPONSE can be used in the Ω mode, if resistances above 50kΩ are being measured the time constant of the filter is increased with a corresponding increase in the time taken for measurement.

7. Press the 10/SEC push-button for repetitive measurement, or alternatively,

8. Press the MANUAL button for 'single shot' measurement.

9. Read the resistance from the display, changing range if necessary.

CURRENT MEASUREMENT

Although current measurement is not a facility provided by this voltmeter, it is easily effected by measuring the potential difference developed across a known precision resistance. The type of resistor used is important: for dc use either a precision wire wound component or, if available, a standard resistor; for ac use a metal film precision resistor.

Alternatively, the Solartron Current Adaptor EX3180, converts any of the voltmeters in this range to an AC/DC digital ammeter capable of measuring currents in the range 1nA to 2A. Full connecting details and operating instructions are given in the manual of the EX3180.

SECTION 4 Measurement Techniques

The user who is only slightly familiar with the practice of precision measurement will find the *MASTER SERIES* of voltmeters very easy to use. The layout and logical operation of the controls, the information presented by the display and the connection of the unknown signal incorporate several new features that have not been provided in other digital voltmeters. This results in an instrument which is so simple that the totally inexperienced can take measurements confident that the control settings and the readings are correct.

The following notes are written for those who wish to know more about the techniques of precision measurement. They also provide a guide as to the best way of employing the voltmeter in more unusual measurement situations.

INPUT RESISTANCE

In making a measurement of voltage virtually all instruments take a current from the source whose voltage is being assessed. The one exception is the true potentiometer in which, at balance, no current is taken from the source. The current taken by the measuring device gives a voltage drop across the internal resistance of the source so that the measured voltage is less than the true emf of the source (Fig. 4.1).

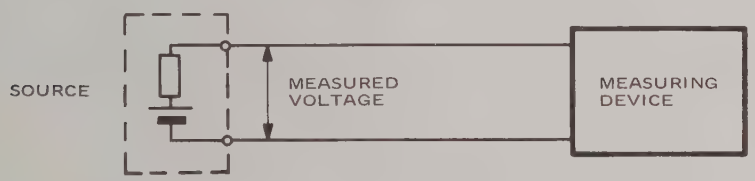


Fig. 4.1 *Current taken by a measuring instrument can cause a voltage drop across source resistance.*

A good moving coil meter will take a current of 10μA (100kΩ/V) so that if the source resistance were 1kΩ the voltage drop would be 10mV. This would be pretty hopeless for 'precision' work since a voltmeter with such a low input resistance would read 1.4900V instead of 1.5000V.

Fortunately electronic feedback techniques can give a digital voltmeter such a high input resistance that in most practical work the effect can be ignored. Thus the A200 series, when measuring dc on the more sensitive ranges, has an input resistance in excess of 10GΩ (1GΩ on 10mV range). This means that the source resistance will have to exceed 1MΩ before an error of 1 digit is obtained. (See also effect of input current discussed later). This may sound a little vague; it is not possible to define the input resistance more closely because a group of voltmeters will have differing gains in their input amplifiers; although this has no effect whatever on the accuracy, the input resistance may be 20GΩ or 53GΩ but will never be as small as 10GΩ.

On the 100V and 1000V dc ranges it is not possible to apply the unknown input directly to the input amplifier; it must be first attenuated. The attenuator must be very accurate and stable and must withstand high input voltages, so wirewound resistors are employed. It is difficult and expensive to make the attenuator of very high value resistors, so a 10MΩ network is used. Hence, on the 100V and 1000V ranges the voltmeter input resistance is 10MΩ ±0.1%, and errors arising from source resistance can be calculated with reasonable accuracy. For example, on the two highest voltage ranges, a source resistance of 1kΩ will cause the result to be 0.01% low, i.e. by 1 digit in 10 000.

INPUT CURRENT

All solid state devices are current operated hence the amplifiers of these voltmeters have a current flowing at the input terminals even when the input signal is zero. By careful design this current can be made almost insignificant and in fact is less than 100pA (10^{-10}A). During warm-up (for about 30 minutes after switch-on) the current will vary, since it has a temperature coefficient of approximately 2pA/^{o}C, and will then stabilise. Taking the input Hi terminal as a reference the current may flow into or out of this terminal and must therefore be regarded as lying between the values of +100 and -100pA.

It should be realised that the effects of input current are additional to the effects of input resistance. Thus, to take a ridiculous example, if on the 10mV range (A200, A203) a 10mV source is measured with a source resistance of 1MΩ the input resistance alone (1GΩ) would give a reading that is up to 10μV low. But an input current of 100pA will introduce an additional error of 100μV which can add to, or subtract from, the error due to input resistance. Thus, in this extreme example, there is uncertainty (rather than a defined error) which may lie anywhere from 110μV low to 90μV high (Fig. 4.2).

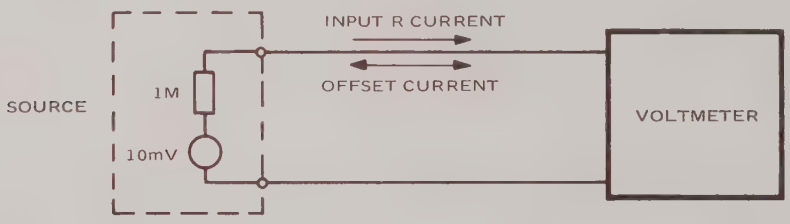


Fig. 4.2 *Current taken by input resistance flows into the Voltmeter; offset current may flow either way. Both effects are present together.*

The conditions given in the above example will probably never be met by the average user because low level signals nearly always have a source resistance of less than 10kΩ, in which case the errors are insignificant. If in a rare situation a low level measurement must be made on a high source resistance the offset current can be monitored and reduced to a very low value in the following way (Fig. 4.3).

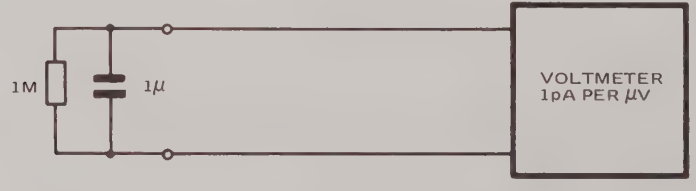
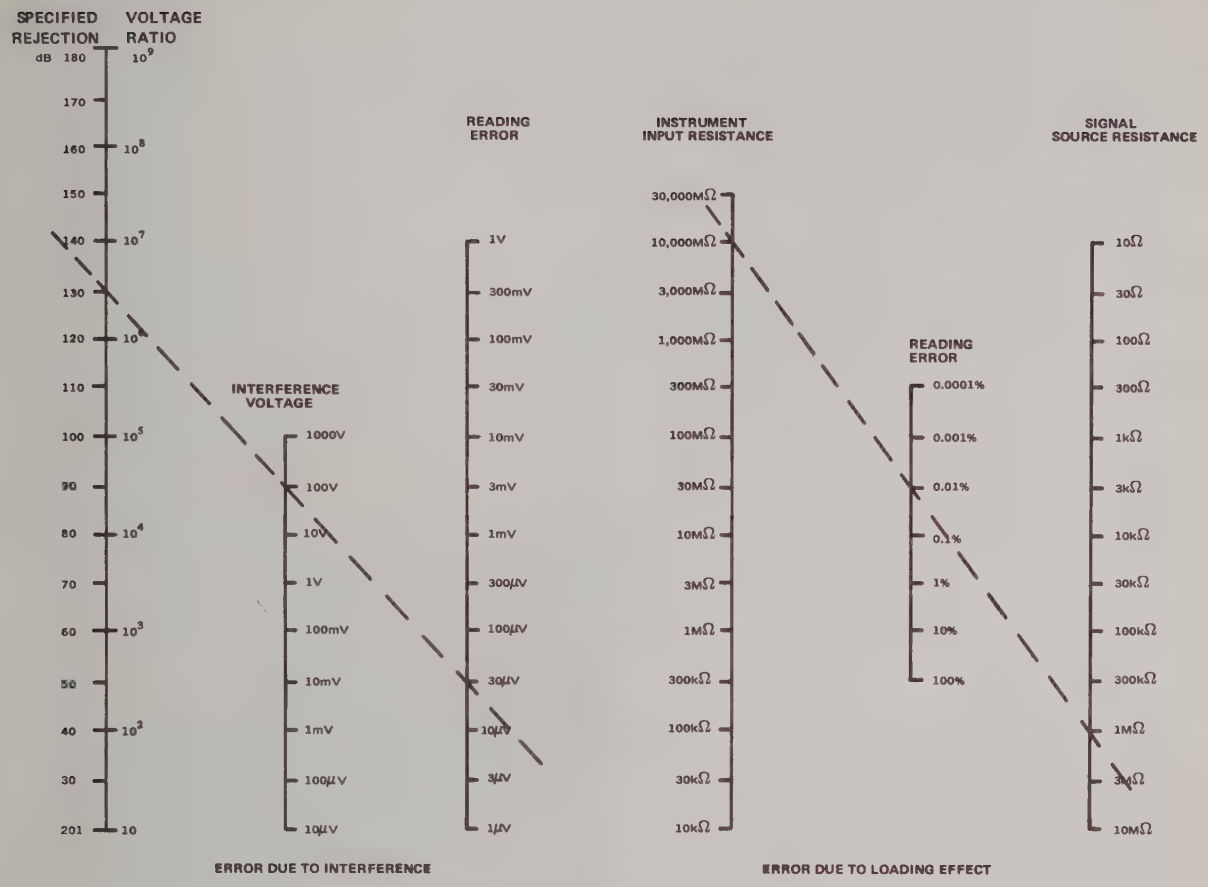


Fig. 4.3 *Using a known resistor the voltmeter can measure its own offset current.*



Remove the top outer cover plate, switch on and allow the instrument to warm-up for 30 minutes. Connect across the input cable a 1M resistor in parallel with a low voltage 1μF capacitor – keep the connections short to minimise 50Hz pick-up. Allow a minute or two for thermal effects to disappear, with a short across the capacitor to dissipate any small dielectric storage; then remove the short circuit.

With the voltmeter on the 10mV range dc (A200, A203) the display represents 1pA per digit, while on the 100mV range (A220, A223) it is 10pA per digit. Through the top of the screened compartment on the right is a pre-set control called INPUT CURRENT which may be adjusted to bring the reading to almost zero. It probably will not stay at zero because very small drifts of a few pA are inevitable, but it will enable a measurement to be made on a high source resistance with less uncertainty in the short term. Over periods greater than a few hours, and with changes in ambient temperature, the current will drift by tens of pA. Hence the formal instrument specification only claims $\pm$100pA for long term use.

ASSESSING INPUT RESISTANCE

From the foregoing it will be realised that it is not possible to check the extremely high input resistance by using instruments as though it were a physical resistor. Furthermore the measurement is complicated by the presence of the offset current.

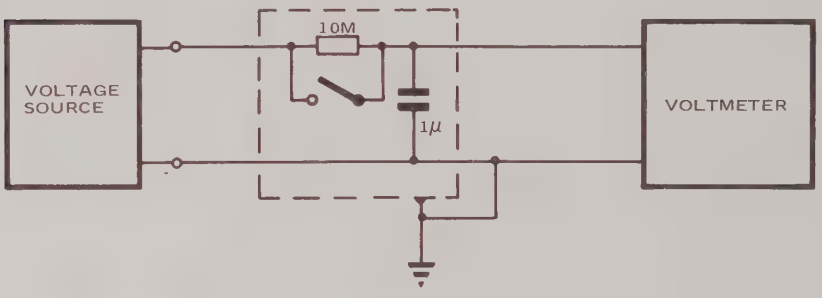


Fig. 4.4 *An assessment of input resistance will include an effect due to offset current.*

With the arrangement shown in Fig. 4.4 the components are mounted in a screening box which is bonded to earth in order to minimise 50Hz pick-up. The voltmeter is set to the 10V dc range and the voltage source to approximately 10V. The switch is first closed and the reading noted, (say 10.057). Upon opening the switch the reading will fall over a short period of time to, say 10.052. Ignoring the offset current this is a fall of 5mV in 10V, which is a factor of 2×10^3. So the input resistance is $2 \times 10^3 \times 10M\Omega = 20G\Omega$.

A proportion of the change will be due to offset current and this will become a greater proportion on the lower voltage ranges. So if any reasonable assessment of input resistance is to be attempted, the current should be first reduced to a few pA as described earlier. As a check the measurement can be made using each polarity of input voltage in turn. A difference in the readings taken with the $10M\Omega$ in circuit will then give a measure of the offset current.

The difficulty of an accurate assessment of input resistance on more sensitive ranges is the only reason why $1G\Omega$ is specified for the 10mV range. The value is probably in excess of $10G\Omega$, but it is impossible to measure it with any reasonable degree of certainty.

SPURIOUS VOLTAGES

Although small emf's occur in the voltmeter input circuits they are compensated for during calibration. Thereafter, when the instrument has warmed-up for about 30 minutes, they are so stable as to be quite insignificant to the user. The drift in the input amplifier is equivalent to an input voltage change of approximately $1\mu V$ per week. The user therefore need not make any compensation or adjustment in order to achieve accurate results.

The voltmeter will faithfully measure any input that is applied to its terminals; it is the responsibility of the user to ensure that the input contains only the voltage that he wishes to measure. In low level work – with perhaps a few tens of microvolts – this may require some care and thought in the arrangement of the circuit.

As an example consider measuring the voltage produced by passing a very small current through a wirewound resistor. On the 10mV range the reading is recorded as $126\mu V$. But the resistor is placed – in the sun or near a power transistor – so that one end is a little warmer than the other.

Because of the dissimilar materials used in the wire of the resistor and in the copper connections a net thermal emf will exist of possibly 40μV/^{o}C. Thus a differential of 0.5^{o}C across the resistor could mean that the true result should be either 106μV or 146μV. The voltmeter cannot possibly distinguish between the wanted and unwanted parts of the signal that is applied to it. In this example, without altering the conditions of the resistor in any way, a measurement should be made with the small current flowing in each direction. In one case the thermal emf will add and in the other it will subtract. So the mean of the two results will eliminate the error.

Metal oxide resistors and reed relays are two other components in which thermal emf's can bring about similar errors. In the reed relay the heating of an operating coil may contribute to this and it may be desirable to employ two reed switches in the same coil so that, when connected in series, thermal emf's are self-cancelling. In the A200 range of voltmeters the reed assemblies, specially developed by Solartron, are used in circuits where these thermal effects are quite insignificant.

When the unwanted emf can be established and it is steady it can be backed off by using the μV ZERO control provided on the voltmeters. This has a range of $\pm$15μV.

In attempting precision measurement of low level signals effects other than thermal emf's can also cause problems. Leakage across an insulating material when degraded by high humidity or an industrial atmosphere may produce an unsuspected voltage across a source resistance. Coaxial cables when flexing under vibration can generate quite high transient voltages due to the screen scrubbing the polythene insulant; use low noise cables.

SERIES MODE INTERFERENCE

The examples of thermal emf's given above can be regarded as forms of interference because they interfere with the accurate assessment of the unknown signal. They are in series with the signal and voltmeter input and represent a special case of series mode interference because there is nothing that the voltmeter can do towards rejecting dc interference while measuring a dc signal.

Series mode ac interference is a different matter. Because of their basic design principle these voltmeters will ignore all the usual forms of ac and noise that may be intermingled with the dc signal. Hence in all normal measurement work the user will be unaware of ac interference and it will not cause errors. Nevertheless it would be possible to introduce such a degree of interference that the voltmeter would be unable to cope, so the keen user may be interested in the mechanism that brings about rejection.

The most common form of ac interference is simple 'hum' – i.e. 50Hz superimposed on the dc signal. This can be visualised either as pick-up on the connecting leads, as shown in Fig. 4.5 (a), or as a generator that is a part of the source, as in Fig. 4.5 (b). In both the result is the same and is shown graphically in Fig. 4.6.

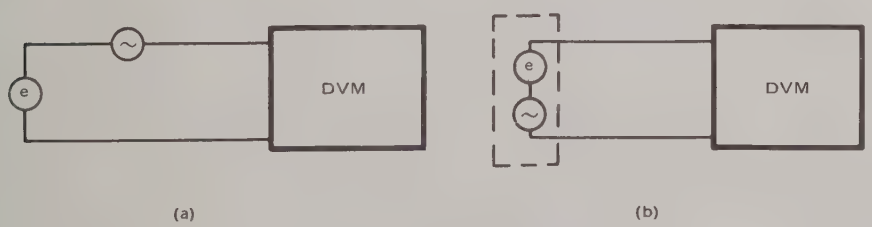


Fig. 4.5 *Interference at 50Hz can arise from pick-up on the leads (a), or may be inherent in the source (b).*

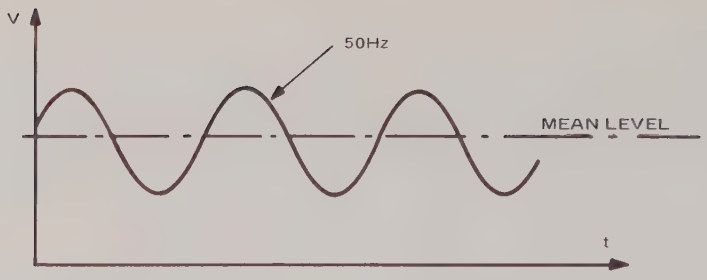


Fig. 4.6 *50Hz superimposed on the dc level that the voltmeter is trying to measure.*

Users of oscilloscopes will be familiar with this sort of picture and will know that the ac component is typically a few millivolts peak-to-peak. This may be superimposed on a wanted dc signal of a mere 100μV.

These voltmeters employ the dual-ramp technique which is described in the Principles of Operation.

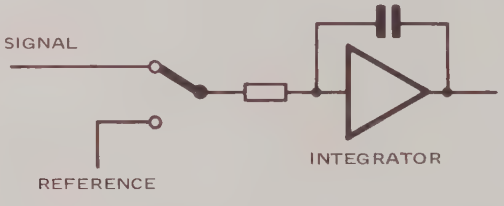


Fig. 4.7 *In the dual-ramp system the integrator is switched first to the signal (ramp-up) and then to the reference (ramp down).*

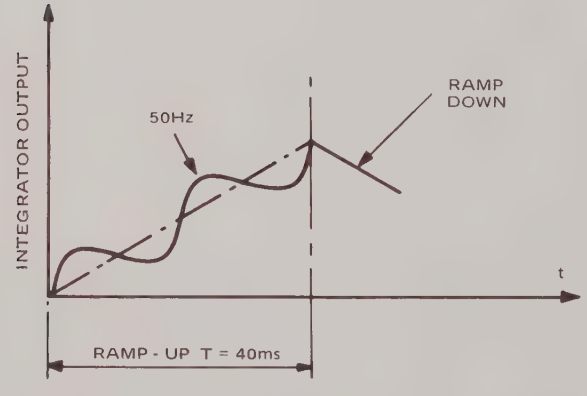


Fig. 4.8 *At the end of ramp-up the integral of any 50Hz component is zero.*

The integrator is connected to the input signal (actually to the output of the input amplifier) to start the initial phase of the measurement. This phase is called 'ramp-up' and lasts for a time that is defined by the frequency of the clock and the capacity of the counter. During ramp-up the output of the integrator is proportional to the integral of its input. If ramp-up lasts for T seconds then it is the integral of the input over T seconds that finally remains on the integrator

capacitor when the switch opens. It is this voltage that is assessed during ramp-down. When T is made equal to the period of the ac interference (or to any whole number of periods) the integral of the ac at the end of ramp-up will be zero. Thus ramp-down starts from a voltage that is proportional only to the dc component (actually to the mean level) of the input. Fig. 4.8 illustrates the situation for a particular case of 50Hz interference.

In this series of voltmeters the ramp-up time (T) is 40ms so that they inherently have rejection of 25Hz, 50Hz, 75Hz, 100Hz..... etc. This is shown by the curves of Fig. 4.9, where rejection notches occur every 25Hz, in which the rejection ratio is given in dB.

To digress for one moment – the decibel (dB) may be unfamiliar to some. It is used here to specify a voltage ratio. The relationship is:

Number of decibels = $20 \log_{10}$ (voltage ratio)

Example: Voltage Ratio = 1000

Number of dB = 20 x 3 = 60dB

dB	Ratio	dB	Ratio
1	1.1	9	2.8
2	1.3	10	3.2
3	1.4	20	10
4	1.6	40	10^2
5	1.8	60	10^3
6	2.0	80	10^4
7	2.2	100	10^5
8	2.5	120	10^6

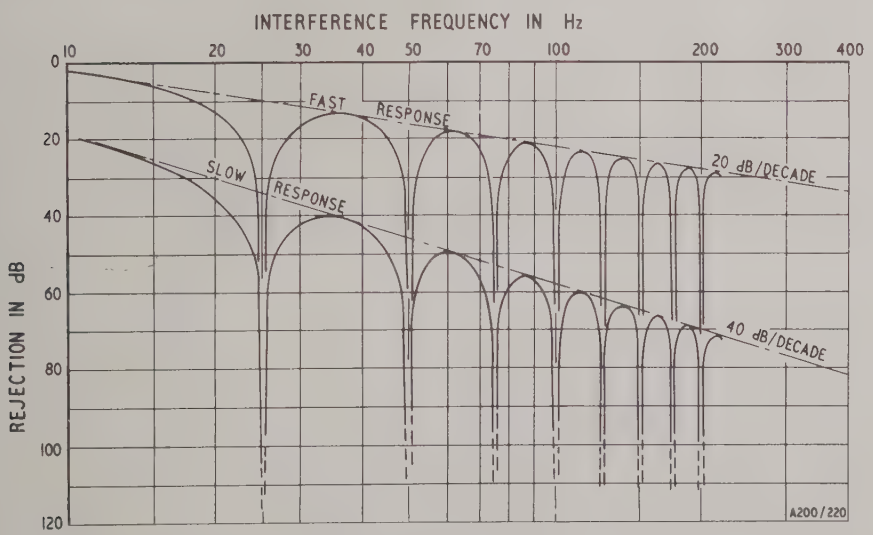


Fig. 4.9 *SERIES MODE REJECTION*

These curves show the rejection that is attained by A220 and A223 for interference with dc measurement at the frequencies given.

A200 and A203 have ramp-up time locked to the mains period so that the curves shift along the frequency axis in step with changes of mains supply frequency.

Decibels add; but ratios must be multiplied. Thus:

$$36dB = 20 + 10 + 6dB$$

$$= 10 \times 3.2 \times 2 = 64 \text{ ratio}$$

If the ramp-up time were precisely 40ms there would be virtually infinite rejection of frequencies at multiples of 25Hz. But the clock frequency cannot be absolutely constant, and although this has no effect on measurement accuracy, the specified rejection must be less than infinite. Hence with A220 and A223 the rejection at 50Hz is better than 60dB; this means that any error will be, at worst, one thousand times smaller than the interference. Usually 50Hz interference arises from the supply mains and occasionally, when the national supply is heavily loaded, this will fall below 50Hz and the integration will be less than perfect. To allow for this as well as for small variations of clock frequency the A220 and A223 specify 36dB for 50Hz $\pm$1%.

Since the precise clock frequency has no effect on the accuracy of the result this frequency may be varied so that ramp-up time is always equal to two mains supply periods. A200 and A203 have a digital servo built in to do this and, as a result, the series mode rejection to mains interference is in excess of 70dB even though the supply frequency may vary by $\pm$2%.

COMMON MODE INTERFERENCE

Interference can also arise from unwanted voltages which are common to both voltmeter leads. Consider Fig. 4.10 – here the signal source is earthed locally and the voltmeter input has also been earthed.

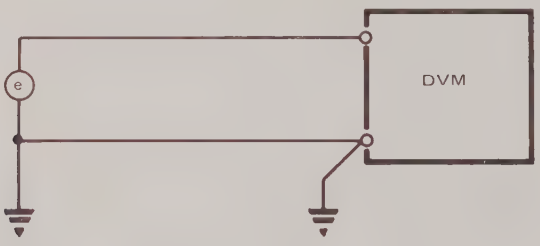


Fig. 4.10 *An 'earth' at both source and voltmeter input may introduce common mode interference. For this reason the voltmeter input is fully isolated.*

There is a distinct possibility that the two 'earths' are not at a common 'zero' potential; in extensive industrial plants widely separated 'earths' can have as much as 10V between them. This situation is equivalent to that of Fig. 4.11 where the source is known to be at a finite potential with respect to earth.

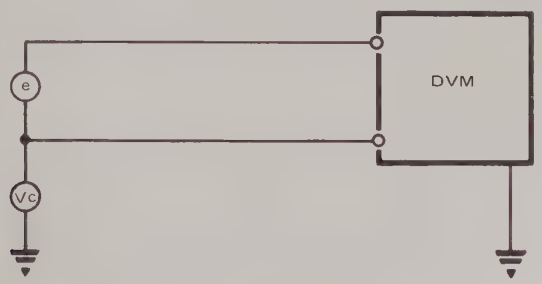


Fig. 4.11 *The source can be at a high potential above earth without causing errors.*

For example, a thermocouple used to measure the temperature of a furnace element might be generating 1mV of dc signal while kept at 240V ac to earth. Obviously it would be ludicrous to earth the voltmeter input, although the chassis and most of the circuits are earthed via the mains supply lead.

All the voltmeters in this series have been engineered so that the input circuits are extremely well isolated from the chassis which is connected to mains earth. In all normal measurement work the small current which is driven down the leads to earth by a large common mode voltage will not cause any error. This voltage should be restricted to 500V purely to ensure safety for equipment and personnel.

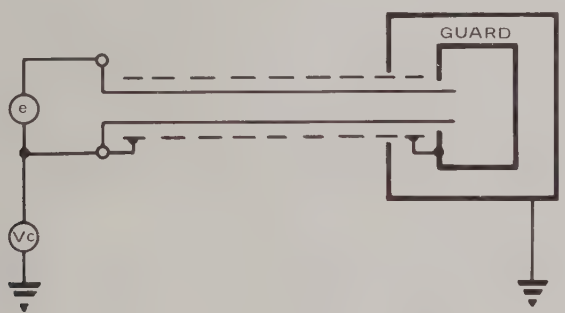


Fig. 4.12 *In the lead provided with the voltmeter Guard is strapped to Lo (BLACK) within the free end of the cable.*

The lead supplied with each voltmeter is shown in Fig. 4.12. Within the instrument the cable screen is wired to the guard box and at the free end the screen is strapped to the black wire. Hence the guard is effectively preserved right up to the signal source and common mode current flowing in the screen and via leakage to earth cannot affect the measurement in any way.

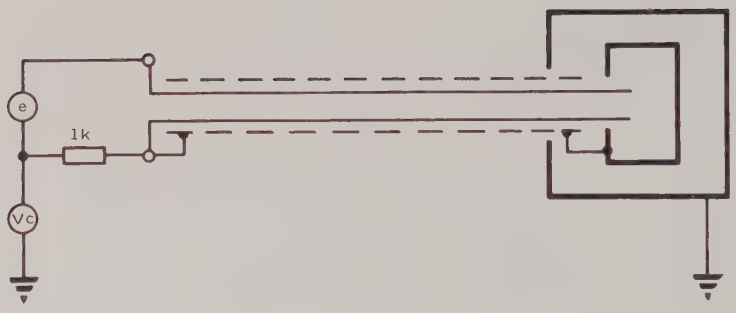


Fig. 4.13 *A rare, but more difficult, situation is where common mode current flows through lead resistance. This is entirely overcome by the arrangement of Fig. 4.14.*

In some measurement situations a common mode voltage can have an affect on the reading. Most users will never meet the problem, but those who do can still eliminate error by using the voltmeter correctly. When there is resistance associated with the source – perhaps inherent in the source, or in connecting leads – the common mode current can flow through this resistance. Examples are: the resistance of strain guages; long compensating leads from a thermocouple. This is illustrated by Fig. 4.13 where it will be seen that current flowing from Vc to earth down the screen must pass through the resistance. If the guard-earth leakage is assumed to be the specified minimum of $10^{10}\Omega$ and Vc is 100V dc the common mode current will be 10^{-8} A. Taking a lead resistance of 1kΩ, 10^{-8} A will give a voltage drop of 10μV. Since the voltmeter cannot reject dc interference the worst error will be 10μV.

If the source of common mode is ac the stray capacitance from guard to earth is more important. The figure specified is 500pF, which is about 6MΩ at 50Hz. With Vc now 100V rms the drop across 1kΩ is approximately 17mV rms or 24mV peak. This appears at the input terminals and the inherent rejection of series mode will be effective in reducing reading error to much less than 24mV. With A200 or A203 the final reading error at worst will not exceed 8μV.

In these examples a 1kΩ resistance has been assumed in one lead. Obviously the magnitude of the error is proportional to this resistance and it is accepted practice to specify common mode rejection with 1kΩ unbalance in the leads using the configuration of Fig. 4.13. Even in these exceptionally adverse circumstances the errors can be overcome by using a different input arrangement as in Fig. 4.14.

This is provided by using a special lead EX3183 from which the 4 cores and the screen are brought out as separate terminations.

Fig. 4.14 shows the EX3183 adapted for three terminal measurements. Alternatively, the EX3193 (three terminals - signal high, signal low and guard) is available.

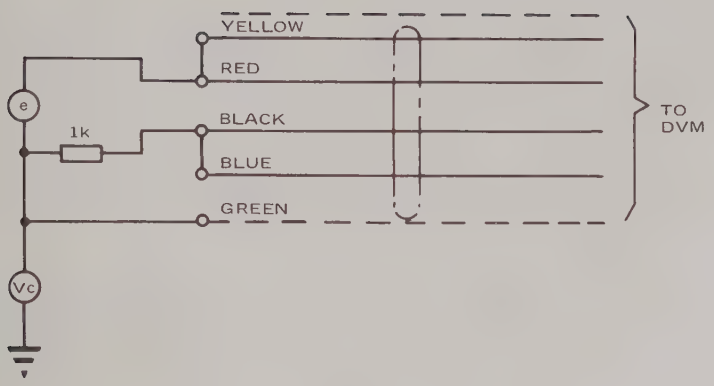


Fig. 4.14 *A special lead (EX 3183) is obtainable from Solartron which enables the Guard to be driven directly by the common mode voltage.*

The 4 cores are required for 4 terminal resistance measurement as described later. For fully guarded voltage measurement only 3 terminals are necessary – signal high, signal low and guard (screen). When on voltage ranges the YELLOW and BLUE cores are connected within the voltmeter to RED and BLACK. To prevent these plugs accidentally making contact with earth, or with other circuits and perhaps causing damage, the YELLOW should be plugged into RED, and the BLUE should be plugged into BLACK. GREEN is connected directly to the source of interference thus driving the guard at the common mode voltage and preventing common mode current flowing through the lead resistance. Using this arrangement, even though the interference were the maximum permitted (500V peak 50Hz), it is most unlikely that there would be any error discernable – even on the most sensitive range.

For a more complete treatment of interference in digital voltmeter measurements the reader is referred to:

1. 'Digital Voltmeters and Interference'
2. 'Principles of Interference Rejection'

both of which are available free on request to Solartron.

NOISE

The foregoing explanation of interference rejection has dealt specifically with 50Hz because by far the most common source of interference is the mains supply, or fields radiated from mains wiring and mains energised equipment. The curves of Fig. 4.9 show that at higher harmonics of 25Hz rejection is improved so that 100Hz ripple from power supplies or 400Hz aircraft and ship supplies are unlikely to introduce difficulty. When considering general 'noise' of no specific frequency the integration process inherent in the dual-ramp technique still applies. The resultant noise component over 40ms integration will tend to zero.

FILTERS

For all normal dc measurement the use of the filter which is built into the voltmeter (SLOW) is unnecessary. Although the increase in response time would be of no consequence during laboratory work, the delay may be of significance in data logging or in automatic test systems. In

these cases the use of FAST will give adequate interference rejection. In rare situations the interference may be so excessive that SLOW produces some benefit on dc measurement. This can be established by changing from FAST to SLOW and observing if there is a difference in reading. If there is a difference SLOW gives the correct answer.

AC VOLTAGE

The unadorned digital voltmeter is able to measure dc voltage only. It can be adapted to measure ac by including an ac-dc converter ahead of the dc input circuits. This has been done in the *MASTER SERIES.*

A203 and A223 include a converter which may be regarded as a sophisticated full-wave rectifier. By including semi-conductor rectifiers in an operational amplifier loop non-linearities in the transmission characteristics of the rectifiers are eliminated. The smoothed output of such a rectifier system is a dc level which is proportional to the *mean* value of the ac; it is this which is passed to the dc voltmeter for measurement. Fig. 4.15 shows this action.

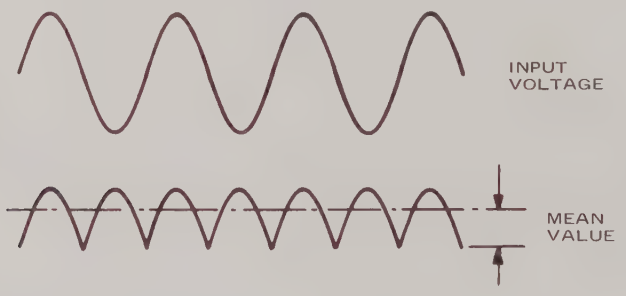


Fig. 4.15 *An ac input voltage is rectified in the ac-dc converter and the smoothed mean value is passed to the dc circuits for measurement. Although the mean value is sensed the rms value is indicated.*

There are three ways of specifying the amplitude of an ac voltage: the mean; the peak; the root-mean-square (rms). For any periodic function there is a precise relationship between these which can be calculated. In the case of a sine wave:

$$\text{Mean} = \frac{2}{\pi} \text{ peak}$$

$$\text{rms} = \frac{1}{\sqrt{2}} \text{ peak}$$

When speaking of ac voltages (e.g. 240V) it is an accepted convention that the rms value is understood unless mean value or peak value is stated. The rms is also used in most calculations. It has therefore become accepted that a measuring instrument will read rms, although the vast majority actually measure the mean. For these reasons A203 and A223 are scaled to give a reading of the rms of the input on the assumption that the input is a perfect sine wave.

Distortion is a factor which can occasionally introduce errors as a result of this assumption. The reader will be familiar with the analysis of a complex waveform which breaks down a periodic function into a fundamental sine wave plus a series of harmonics. It is the harmonics which represent the distortion content, the degree of distortion being dependent upon the order,

the amplitude and the phase of the harmonics. It will be extremely rare that the detailed harmonic content is known, but what may be known is the Total Distortion which is, in effect, the sum of the total harmonic content. Measurement errors would be greatest for a mean sensing rms indicating instrument is the total distortion was all third harmonic. Hence this assumption would enable an estimate to be made of the worst possible errors. In this case:

$$\text{Max percentage error} = \frac{1}{3} \text{ total percentage distortion.}$$

Thus a total distortion of 0.3%, if all third harmonic, could give a worst error of 0.1%.

The voltmeter input impedance on ac is either 1MΩ or 10MΩ (depending on range) in parallel with a capacitance. At frequencies above a few tens of Hz the capacitive term will be dominant. The values are given in the formal specification and may be used to calculate the voltage drop across a source impedance at a particular frequency.

Consideration of Fig. 4.15 will show that the lower the signal frequency the more smoothing is necessary before the mean level can be passed into the dc measuring circuits. Therefore below about 100Hz a longer time constant filter (SLOW) is required in order to preserve measurement accuracy. AC measurement with a digital voltmeter gives easily the best compromise between speed and accuracy over all other forms of ac measurement. But with low frequencies, using any measurement technique, the reading must have time to settle.

It has been pointed out that when measuring dc voltages the voltmeter cannot reject thermal or other dc interference. In exactly the same way there cannot possibly be rejection of series mode ac interference when measuring ac voltages. Common mode rejection is, however, still preserved, and the input circuits on ac are still fully isolated from chassis and from earth. For those who are interested in pursuing the subject in greater depth a paper on AC Voltage Measurement, with particular reference to waveform errors, is available free on request to Solartron.

RESISTANCE

Voltmeters A203 and A223 measure the value of a resistor by passing a defined current through the resistor and determining the potential difference that results. The current is small (600μA on 1kΩ range) so that power dissipated in the resistor is minimised. In measuring low values of resistance the voltage dropped along the current carrying leads can sometimes introduce errors. In these instruments, when using the lead provided, the effect is entirely eliminated by operational amplifier techniques within the voltmeter.

The most sensitive resistance range of 1kΩ with its 100mΩ sensitivity is satisfactory for most low value measurements. Should there be a requirement for increased sensitivity on low values the voltmeter can be used on a dc voltage range to measure the potential difference across the resistor with a current provided from an external source (Fig. 4.16).

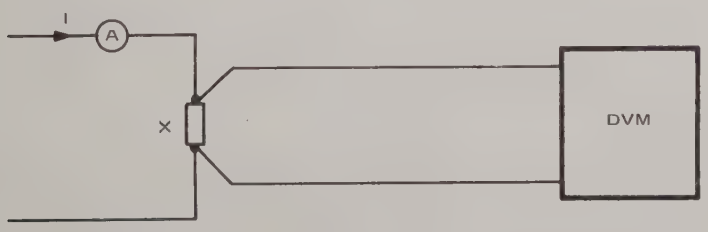


Fig. 4.16 *A very low value resistance may be measured by measuring the voltage devloped across it. The voltage leads should be connected close to the ends of the resistor.*

If I is 1mA and the voltmeter is on the 10mV dc range a reading of 12.63$\dot{1}$mV means that x is 12.631Ω. Obviously other appropriate currents and voltage ranges could be used. The first point to observe is that, in this example, the sensitivity is 1mΩ per digit. Hence the voltmeter connections must be made right at the ends of the resistor and must not embrace any significant length of the current carrying leads (10cm of 22SWG copper wire is approximately 4mΩ).

A second point is that the accuracy is affected directly by the precision of the current setting. There would be little point in using a moving coil multimeter to set current and then record a reading of 12.631Ω.

An improved technique is shown in Fig. 4.17.

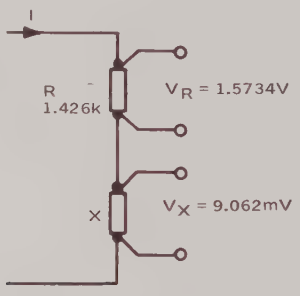


Fig. 4.17 *A ratio measurement avoids having to set a precise value of current.*

Here a resistor R, whose value is known, is connected in series with the low value unknown x. R can be a much higher value than x. If R is not already known it can be measured on one of the ohms ranges. The voltmeter, on dc auto-range, is connected across R and the current supply is adjusted to give a reading greater than half full-scale. The precise value of V_R is not important; neither is the value of the current I. In this example I could be simply provided by a 1.5V dry cell. The reading V_R is recorded. The voltmeter is transferred to x and the reading V_x is noted. The value of x is then given by:

$$x = R \frac{V_x}{V_R} \text{ ohms}$$

Using the values shown in Fig. 4.17:

$$x = \frac{1.426 \times 10^3 \times 9.062 \times 10^{-3}}{1.5734} = 8.213\Omega$$

If x is being set to different values it may be necessary to measure V_R each time because, unless I comes from a constant current supply, changes of x may significantly alter I.

Should it be necessary to measure resistance at a distance from the voltmeter which is beyond the reach of the standard input lead, a special lead EX 3183 may be obtained from Solartron. In this the four cores and screen are terminated separately, as shown in Fig. 4.18. This cable should be extended to reach the point of measurement by means of a similar 4 core screened cable, and connected to the remote resistor as shown.

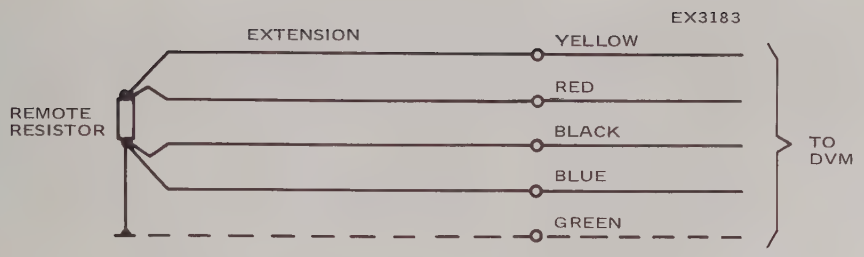


Fig. 4.18 *In measuring a remote resistor, lead compensation can be preserved by using the special input cable (EX 3183, obtainable from Solartron) and extending it by a 4 core screened cable.*

This arrangement will preserve the compensation for lead resistance on any ohms range up to a maximum of 1Ω per wire. Using an extension of 7/.0076 wires a length of 100m can be safely used.

CURRENT

For determining current (dc or ac) the voltmeter can be used to measure the voltage drop when the current is passed through a known resistor and the value of the current thereby calculated.

If currents of the same order are to be measured frequently, the provision of a resistor of suitable value can save the chore of calculation. For example with a 1Ω resistor and the voltmeter on the 1V range currents up to 1.9999A can be determined by direct reading amps instead of volts. If the results are to be consistent with the accuracy of which the voltmeter is capable the resistor must be known precisely. This can be achieved by taking a value that is slightly high and wiring others in parallel while measuring the total value as described earlier. The main resistor should be a precision type capable of good stability; wirewound is suggested for dc work, but for ac measurement metal film resistors should be used to avoid inductance effects.

In applications where a wide range of currents are to be measured the Current Adaptor EX 3180 should be considered. This has precision resistors built-in. When used with a Voltmeter in the *MASTER SERIES* current ranges of 1A down to 10μA can be selected by push buttons giving a maximum sensitivity of 100pA.

LONG TERM INTEGRATION

In measuring a steady dc input the number of pulses gated to the counter during ramp down is the measure of the input voltage. If this number of pulses is p:

$$p \propto \text{input voltage}$$

actually $$p \propto \frac{1}{T}\int_0^T v(t)dt$$ where $v(t)$ is a varying input

T is ramp-up time

or $$p \propto V \text{ where } V = \frac{1}{T}\int_0^T v(t)dt$$

On a given range each single pulse results in 1 digit in the display, and the value of 1 digit depends upon the range. Thus if 1 digit represents S volts (Sensitivity), p digits (i.e. p pulses) represents pS volts.

But on A200 and A220 display at nominal range is 10 000.

Thus $S = R \times 10^{-4}$ where R is nominal range value in volts.

(e.g. on 100mV range, $S = 100 \times 10^{-3} \times 10^{-4} = 10\mu V$).

Then $V = pR \times 10^{-4}$ for each individual reading.

If N readings are taken: $V = \frac{Np}{N} R \times 10^{-4}$

But Np is the total pulses accumulated during N measurements.

Put $Np = P$

Then $V = \frac{P}{N} R \times 10^{-4}$

In a time t secs there are $10t$ readings, so $N = 10t$:

$$V = \frac{P}{10t} R \times 10^{-4}$$

$$V = P \frac{R \times 10^{-5}}{t} \text{ volts}$$

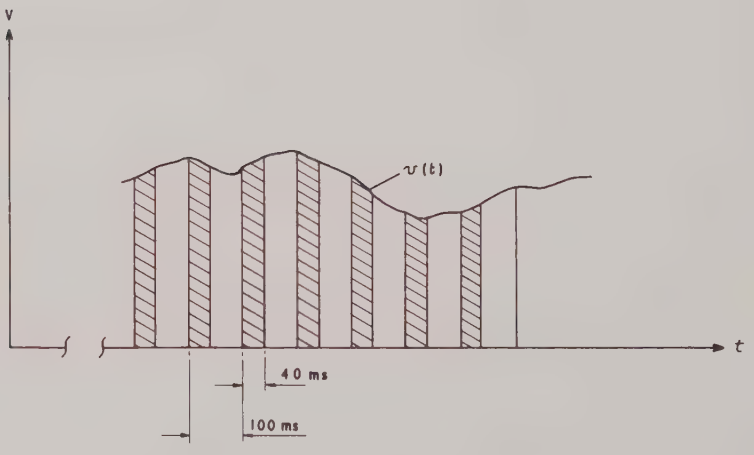


Fig. 4.19 *Long term averaging process*

As ramp-up lasts for 40ms a long term measurement is the result of repeatedly taking the average value over 40ms in each 100ms (Fig. 4.19). Thus the final average value will be correct only when the variations in the input are slow relative to 100ms. This is exactly the situation in which long term averaging is required – for example, gradual variations in a chemical plant. Obviously it is valid only when the input is continuously of one polarity, since the gated pulses do not contain polarity information.

Thus a long term average of a slowly changing input may be obtained by taking the output from pin k on the fan-out unit to an external counter.

$$\text{Average} = \frac{\text{total count x nom. range in volts}}{\text{count time in seconds}} \times 10^{-5} \text{ volts.}$$

SECTION 5 Data Systems Use

SYSTEMS USE

The addition of a fan-out unit makes this voltmeter eminently suitable for use in a data logging or automatic test system. It enables full remote control of all the front panel functions (except power) and provides display information and the various control signals necessary in such systems.

INSTALLATION OF FAN-OUT UNIT A204

1. Release the two side panel captive securing screws and withdraw the side panels.
2. Remove the top cover.
3. Remove the blanking plate.
4. Insert the fan-out unit into the connector provided and, using the blanking plate screws, secure the fan-out socket to the rear panel.
5. Replace the top and side covers and secure.

RACK MOUNTING

Included with the accessories is a pair of combination handles/rack mounting ears for substitution with the standard handles. This is effected by removing the four handle retaining screws and the handles, and replacing with the rack ear/handles using the same screws.

In addition, if space is required between instruments within the rack for rack runners, it is necessary to remove the lower side panel retaining strips and the bottom cover, as follows:-

1. Release the rear feet.

2. Slide out the side panels.

3. Remove the lower retaining strips.

4. Remove the bottom cover.

The side panels may be replaced.

FAN-OUT FACILITIES (at rear socket)

PIN	FUNCTION	PIN	FUNCTION
A	1×10^0	d	Polarity +
B	2×10^0	e	Polarity –
C	4×10^0	f	1 BCD
D	8×10^0	h	2 Range Information
E	1×10^1	j	4 (See Output Information)
F	2×10^1	k	Gated Clock
H	4×10^1	m	1 BCD
J	8×10^1 Staticised Display	n	2 Range Command
K	1×10^2 Information	p	4 (See Remote Command)
L	2×10^2 BCD	r	Command CONTROL (LOCAL/REMOTE)
M	4×10^2	s	Contact Sample
N	8×10^2	t	Pulse Sample
P	1×10^3	u	Print Command (Pulse)
R	2×10^3	v	Print Command (Level)
S	4×10^3	w	Data is Changed (See Remote Command)
T	8×10^3	x	Data can Change (See Output Information)
U	1×10^4	y	Command AUTO range
V		z	Command RESPONSE (FAST/SLOW)
W		AA	Command MODE (DC, AC or Ω)
X		BB	(A203 and A223 only)
Y		CC	MODE Identification
Z		DD	(A203 and A223 only)
a		EE	
b		FF	
c		HH	0V

REMOTE COMMANDS

Remote control of the instrument is possible only when Fan-Out Unit A204 is fitted. Before applying remote commands to the instrument, REMOTE must be selected either electrically (at pin r of A204) or by the front panel switch.

Input Levels

Level '1' is $+2.4V < \text{'1'} < +6V$ at $100\mu A$ or open circuit

Level '0' is $-0.5V < \text{'0'} < +0.5V$ at 5mA sink

CONTROL

CONTROL	Pin r
LOCAL	1
REMOTE	0

Note: If LOCAL is commanded whilst the REMOTE switch is in, then the only switches under LOCAL control are POWER and RATE.

RANGE

Ranges are selected by addressing pins m, n and p with 1, 2, 4 B.C.D. If the decimal value of the range code is 'N' then the full scale (nominal) commanded is:

1×10^{-N} kV (A200, A203, A220, A223)

or $1 \times 10^{(1-N)}$ MΩ (A203, A223)

depending on the MODE selection.

Voltage Range	Range Code			N	Resistance Range
	p (4)	n (2)	m (1)		
1000V	0	0	0	0	10MΩ
100V	0	0	1	1	1MΩ
10V	0	1	0	2	100kΩ
1V	0	1	1	3	10kΩ
100mV	1	0	0	4	1kΩ
10mV (A200 A203 only)	1	0	1	5	—

Note: If 101 is applied when either AC or Ω is selected or for A220 and A223 the 100mV or 1kΩ range will be called.

If 110 or 111 is applied the 1000V or 10MΩ range will be called.

MODE

Available on A203 and A223 only.

MODE	Pin AA	Pin BB
DC	1	1
AC	0	1
Ω	1	0

AUTO RANGE

Auto range is selected by Level 0 at pin y.

RESPONSE

RESPONSE	Pin z
FAST	1
SLOW	0

RATE

Manual: If MANUAL has been selected by the front panel control, the instrument need not be in the REMOTE mode to be able to initiate measurements by pulse or contact sample.

If 10/SEC has been selected by the front panel control, either MANUAL must be selected or REMOTE control commanded by a 0 level at pin r of the rear socket before pulse or contact sample can be used to initiate a measurement.

If REMOTE has been selected by the front panel control, the MANUAL control must also be pressed once (to release 10/SEC button) before measurements can be initiated by pulse or contact sample.

Contact Sample: Contact closure between pins s and 0V (HH) with less than 2ms contact bounce.

Pulse Sample: Positive pulse at pin t of $>10\mu s$ duration and between +3V and +8V amplitude.

Pulse or Contact sample can be applied any time while Print Command Level is at '1' but preferably not earlier than 5ms after new range/mode/channel selection.

Repetitive: Press the REMOTE and 10/SEC push buttons but do *not* command REMOTE. Then the remote control of other functions is retained.

To change from continuous to pulse or contact sample, command REMOTE by 0 level at pin r.

DATA IS CHANGED

This input enables the user (system) to instruct the voltmeter that a settling time is required before the next measurement, because of a change of range and/or mode command data.

If command data is unchanged apply '0' at pin w

If command data is changed apply '1' at pin w

If the new command data is different, the '1' must be applied after DATA CAN CHANGE has gone to '0' and before SAMPLE (Pulse or Contact) command; this '1' must be maintained until DATA CAN CHANGE next goes to '0'. Thus, when the command data is different the internal digitise command will occur 10ms after SAMPLE command, whereas if it is unchanged the internal digitise command will occur 1ms after SAMPLE command.

OUTPUT INFORMATION

Output Levels: Level '1' is +2.4V $<1<$ +6V from 6kΩ source

Level '0' is -0.5V $<0<$ 0.5V at 10mA sink

RANGE

There are two possible range output codes; Code 1 is identical to the range command code whilst Code 2 simplifies the interpretation of the output data, allowing the value to be read as; Reading (as an integer) x 10^{-N} V or kΩ. This effectively means that the range number, N, fixes the decimal point N places from the right of the measurement data and allows the value to be read in volts or kilohms.

The code is set by a single link on pcb No. 27 of the Fan-Out. Code 2 is normally connected before dispatch except when the dvm is supplied with a Compact - 33 Logger. To change to code 1 locate pins A, B and C at the bottom of pcb No. 27. If A and B are linked Code 2 is connected. The link should be moved to connect pins A and C for Code 1.

Code 1 (as Range Command)

Voltage Range	Range Output Code			N	Resistance Range
	j (4)	h (2)	f (1)		
1000V	0	0	0	0	10MΩ
100V	0	0	1	1	1MΩ
10V	0	1	0	2	100kΩ
1V	0	1	1	3	10kΩ
100mV	1	0	0	4	1kΩ
10mV	1	0	1	5	–

Value = Reading (as an integer) x $10^{-(N+1)}$V or x 10^{-N} kΩ

Code 2 Voltage Range Output:

Voltage Range	Output Code			N
	j (4)	h (2)	f (1)	
1000V	0	0	1	1
100V	0	1	0	2
10V	0	1	1	3
1V	1	0	0	4
100mV	1	0	1	5
10mV	1	1	0	6

Formula = Reading (as an integer) x 10^{-N} Volts

Code 2 Ohms Range Output:

Ohms Range	Output Code			N
	j (4)	h (2)	f (1)	
10MΩ	0	0	0	0
1MΩ	0	0	1	1
100kΩ	0	1	0	2
10kΩ	0	1	1	3
1kΩ	1	0	0	4

Formula = Reading (as an integer) x 10^{-N} Kilohms

MODE

MODE	Pin CC	Pin DD
DC	1	1
AC	0	1
Ω	1	0

POLARITY

Polarity	Pin d	Pin e
Positive (+)	1	0
Negative (−)	0	1

AC and Ω indication is the same as positive polarity. This information is staticised.

OVERLOAD

Condition	Pin c
Not overloaded	0
Overloaded	1

PRINT COMMAND

Level: In "repetitive" (10/SEC) mode, pin v is at 0. In MANUAL pin v is at 1 except during digitisation when pin v is at 0.

Pulse: At the end of ramp down, a positive pulse (from 0 to 1) at pin u of duration 10μs.

In the instances where the voltmeter requires an extra settling time (as indicated by the WAIT light on the front), Print Command is not generated until after the required WAIT time. Thus, Print Command incorporates the WAIT facility to indicate that the display has not been updated with the result of the latest measurement.

DATA CAN CHANGE

This signal instructs the user (data system) that new Range or Mode command data can be applied.

Data Can Change	Pin x
Yes	0
No	1

GATED CLOCK

Pin k presents the clock pulses which are counted during ramp down.

OPERATING SPEED

The most important factors which govern the speed at which a data logging system can run are:

1. The delays introduced by the input scanning device.

2. The voltmeter digitisation time.

3. The time taken by the output device to record the reading.

Additionally, off-limit detection will introduce a delay.

Scanner Delays

These consists of the "sample command delay" and the "break before make gap". The sample command delay is the period between the moment a scanner relay is called and the moment sample command (Pulse or Contact Sample) is given. The break before make gap is the time between the release of one channel and the calling of the next; this is incorporated to ensure that no two channels are ever connected in parallel.

Digitisation Time

This depends on the following factors:

i) Time between start of integration and when the reading is available. For fixed range operation this time is between 40 and 80ms, depending on the reading.

ii) Internal delays introduced to give extra settling time if the commanded data is changed (10ms) or SLOW is commanded (approximately 1s).

iii) When the sample command is issued relative to the conversion cycle. On A200 and A203 integration starts only at every 5th cycle of the mains supply frequency, thus a delay of up to 100ms can occur before integration. Although A220 and A223 are not mains locked the time between integrations is the same.

iv) In addition, if AC SLOW is commanded, the sample command delay must be at least 4s to allow the input circuits to settle before a sample command is given.

Thus the maximum digitisation times for fixed range operation are:

DC FAST	$\geqslant$ 180ms*
DC SLOW	$\geqslant \triangleq$1.2s
Ω FAST	$\geqslant$ 180ms*
Ω SLOW	$\geqslant \triangleq$1.2s
AC FAST	$\geqslant \triangleq$1.2s
AC SLOW	$\geqslant \triangleq$1.2s+

*plus 10ms if commanded data is changed.

+plus 4s extra settling time that must be included in the sample command delay.

If auto ranging is used the times as given in the specification apply.

Recording Time

The time taken by an output device to record a reading may or may not affect the system speed. If the recording device has a built in staticiser (a buffer which stores the result), then the reading can be transferred almost instantaneously. This enables the voltmeter to be released for digitisation of the next measurement while the previous result is being recorded, (provided the recording time does not exceed 60ms).

More common, however, are the serial recording devices with which the time taken depends upon the number of characters to be recorded. For the recorders normally used by Solartron, the nominal times are:

Addo X Printer	55ms per character +350ms
Clary 35 Printer	60ms per character +150ms
IBM 'B' Typewriter	100ms per character +500ms approx. per new line
ASR 33 Teleprinter	100ms per character
Addo 5 Punch	55ms per character
Facit 4070 Punch	13.3ms per character
DD110 Punch	9ms per character +9ms
RDL 10000 Tape Recorder	1ms to 2.5ms per character (depending on packing density)

HIGH SPEED REMOTE CONTROL

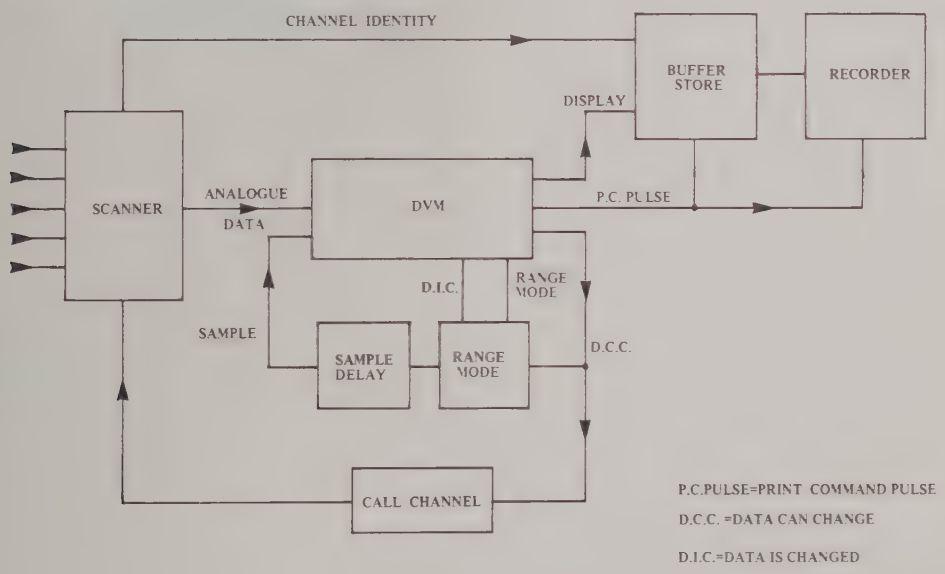


Fig. 5.1 Basic Logging System

Figure 5.1 shows a typical arrangement of a digital voltmeter (dvm) controlled externally in a data logging system. In this example, the recording device must be capable of completing the record within 60ms so that the system can operate at 10 channels per second, the fastest possible recording speed. The dvm measures sequentially the voltages from a number of input channels. The range and mode information is pre-programmed and may change from one channel to the next.

The operation is as follows: with the first channel connected to the dvm a sample is manually initiated (by either the MANUAL button or CONTACT SAMPLE for example); PRINT COMMAND goes low (DATA CAN CHANGE goes high) and the dvm measures the input starting at the first available complete conversion cycle. At the end of measurement the following occurs:

i) PRINT COMMAND goes high to initiate the transfer of the display information into the buffer/store.

ii) DATA CAN CHANGE goes low a) to enable a Range and/or Mode change if it is required, b) to command the application of the next channel.

If the new Range and/or Mode is different from the previous measurement DATA IS CHANGED must be taken high to increase the internal delay thereby giving the extra settling time required.

When the next channel is connected the sample delay is initiated. This delay ensures that the scanner relay contacts have settled. At the end of the sample delay PULSE SAMPLE is generated to instruct the dvm to start measurement of the new channel.

The timing of these events, shown in figure 5.2, is critical and is governed by the following rules:

i) PULSE SAMPLE: This must occur not earlier than 5ms after selection of range/mode/channel whichever is the latest.

For the highest recording rate (10 channels per second) the latest time that PULSE SAMPLE can be generated (assuming the worst case when the previous reading was full scale) is:

either approximately 10ms(*) after PRINT COMMAND (and DATA CAN CHANGE) if DATA IS CHANGED is high (data changed)

or is approximately 19ms(*) after PRINT COMMAND (and DATA CAN CHANGE) if DATA IS CHANGED is low (data not changed).

* The exact period is determined by the clock frequency which for A200 and A203 is fixed by the mains supply frequency.

Hence the sample delay must be >5ms and the break before make gap plus the sample delay must not exceed 10ms (or 19ms).

If AC and SLOW are commanded the sample delay must be increased by 4s to allow sufficient settling time.

ii) DATA IS CHANGED: This command must be applied after PRINT COMMAND has gone high (DATA CAN CHANGE has gone low) and before PULSE SAMPLE, and must be maintained until DATA CAN CHANGE next goes low.

Normally, as in the system described, DATA IS CHANGED would be coincident with the new channel selection.

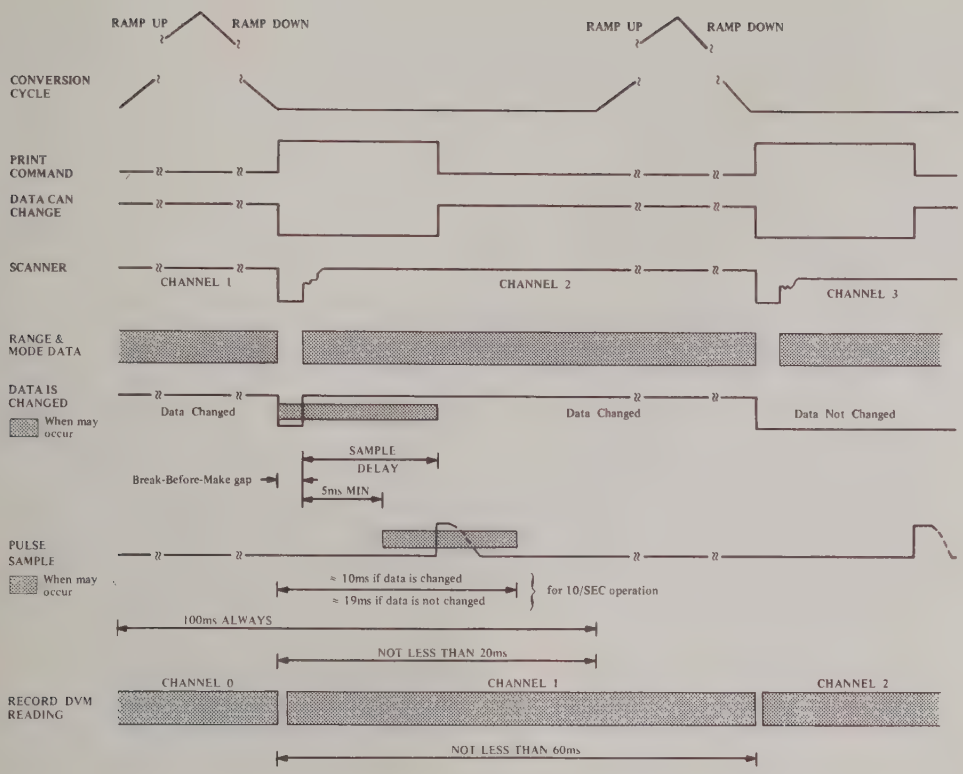


Fig. 5.2 Timing

SECTION 6 Principles of Operation

DUAL RAMP

The basic measuring circuit used in these instruments is a bipolar analogue to digital converter operating on the dual ramp principle.

In this technique the unknown input is caused to charge a capacitor for a fixed time. Then, with the unknown removed, a reference voltage is used to discharge the capacitor. The time taken to discharge the capacitor is a measure of the unknown. To ensure that the charge and discharge are linear an integrator is used.

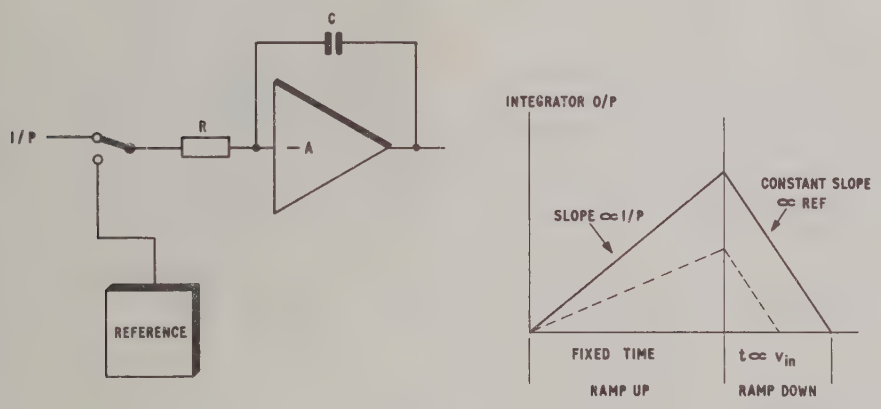


Fig.6.1 Basic Principle

When the integrator is connected to the input its output 'ramps up' at a rate which is directly proportional to the value of the input. After a fixed time the switch changes over and connects the reference in place of the input. It is arranged that the reference voltage is of opposite polarity to that of the input, so that the integrator output now 'ramps down' at a fixed rate which is determined by the value of the reference. The time taken to 'ramp down' is a direct measure of the unknown. The ramp up time can be defined and the ramp down time measured by the arrangement shown below.

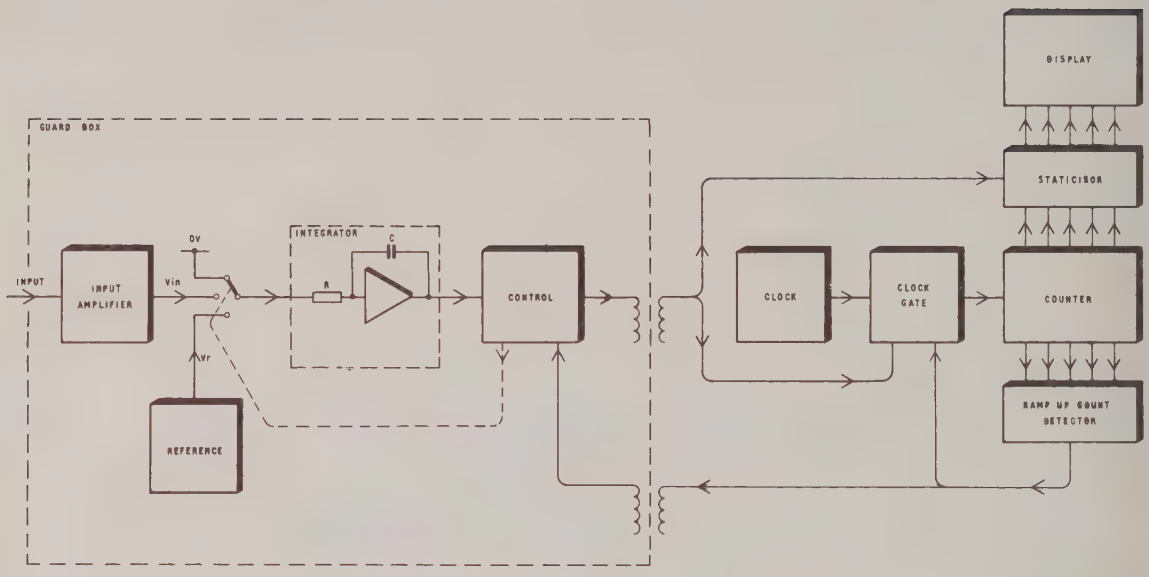


Fig.6.2 Basic Dual Ramp Block Diagram

A measurement cycle is started by the control switching the integrator to the input. At the same time the counter is set to zero and the gate opened. Pulses from the clock then accumulate in the counter while the integrator output rises as a ramp. If the counter has a "full house" of 19999, then the 20000th pulse will return it to zero. It is arranged that when the 20000th pulse is entered, the output pulse generated as the counter resets, causes the control to disconnect the integrator from the input. Ramp up is thus terminated after a period dependent upon the clock frequency and the counter "full house"; a 500kHz clock giving a nominal ramp up time of 40ms.

At the end of ramp up, a voltage (V_1) will have been stored on the integrator capacitor. This voltage is

$$V_1 = \frac{VinT_1}{CR} \quad volts \qquad (1)$$

where:- Vin = input voltage

T_1 = ramp up time

C and R are the integrator components

The reference (of opposite polarity to the input) is now connected to the integrator which begins ramp down towards zero at a rate proportional to the reference. Meanwhile, clock pulses are still being applied to the counter, which started from zero again as ramp down commenced.

When the ramp reaches zero the gate closes and the control causes the reference to be disconnected from the integrator. Hence ramp down is terminated.

The number of pulses in the counter is directly related to the time taken for ramp down and, because the reference voltage is constant, it is also proportional to V_1 which was stored at the end of ramp up.

If, during ramp down, the integrator output at time t is V_2 and the reference voltage is Vr, then:

$$V_2 = V_1 - \frac{Vr\ t}{CR}\ volts \qquad (2)$$

and after T_2 (ramp down time) when $V_2 = 0$ then:

$$V_1 = \frac{Vr\ T_2}{CR}\ volts$$

Hence, from (1) and (2)

$$\frac{VinT_1}{CR} = \frac{VrT_2}{CR}$$

$$\therefore\ Vin = Vr\ \frac{T_2}{T_1}\ volts$$

Now the number (N) of clock pulses accumulated in the counter for a clock frequency of fHz is:-

$$N = T f\ pulses$$

Thus $$T = \frac{N}{f}\ seconds$$

$$\therefore\ Vin = Vr\ \frac{N_2}{f} \cdot \frac{f}{N_1}$$

$$Vin = Vr\ \frac{N_2}{N_1}$$

But Vr and N_1 are constant, therefore

$$Vin \propto N_2$$

and is independent of clock frequency.

Thus the number of pulses accumulated by the counter during ramp down is directly proportional to the voltage being measured.

The *MASTER SERIES* of instruments operate basically as described but with certain refinements which significantly improve both accuracy and series mode rejection.

1) In the A200 and A203 only, a digital servo system continuously monitors the 50Hz mains frequency and, by modifying the clock frequency, ensures that ramp up lasts for exactly two mains periods.

2) A 4μs delay is introduced between the end of the ramp up period and the beginning of ramp down. This allows time for the correct polarity reference to be selected and prevents the possibility of inaccuracies due to switching transients.

3) After completion of ramp down, which can last for up to 40ms, a minimum of 20ms is available before the start of a new measurement for drift correcting the integrator (A200, A203, A220 and A223) and frequency adjusting the clock (A200 and A203 only).

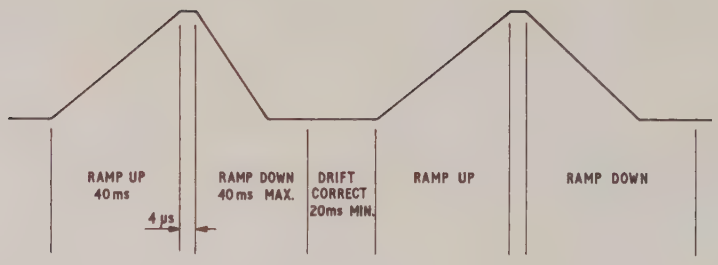


Fig.6.3 Sequence of Operation

DC MEASUREMENT

For dc measurement the integrator is preceded by an input amplifier using feedback. This arrangement increases the input impedance of the voltmeter and facilitates range switching.

AC MEASUREMENT

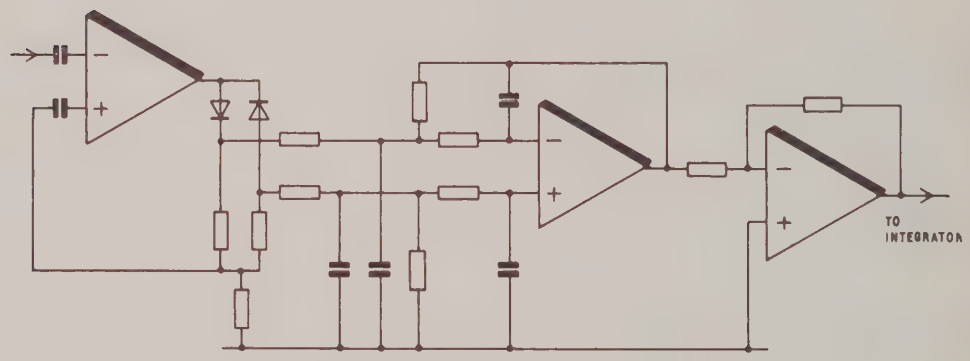


Fig.6.4 AC Measurement

For measurement of ac, the integrator is preceded by an operational rectifier, followed by a filter and an amplifier to obtain a dc signal referred to a common 0V. This dc signal is proportional to the mean rectified ac signal and is scaled by a factor of 1.11, to represent the rms value of a sine wave input, before being applied to the integrator. Thus, the ac is continuously converted to dc for subsequent application to the integrator. Ranging is effected by an input attenuator.

RESISTANCE MEASUREMENT

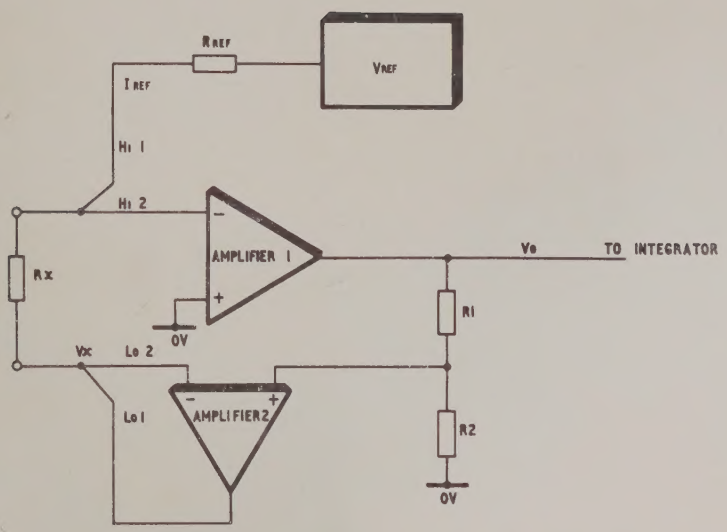


Fig. 6.5 Resistance Measurement

Basically, resistance is measured by measuring the potential developed across the unknown resistor when a known reference current is passed through it.

In the system of resistance measurement used in the A203 and A223, great care has been taken to minimise errors caused by lead resistance. A four terminal technique is used, two terminals apply the reference current whilst two terminals sense the potential difference across the resistor. However, on the standard input lead the connection of the sense leads to the supply leads is effected inside the cable.

Rx, the resistance being measured, is made part of the potential divider comprising R_{REF} and Rx. This divider is connected between V_{REF} and the output of voltage follower Amplifier 2. The output (Vx) of Amplifier 2 is proportional to the output (Vo) of Amplifier 1. Amplifier 1 senses the potential at the junction of R_{REF} and Rx.

At equilibrium, Vx will be such that the voltage at Hi 2 is the input amplifier error voltage which is very nearly zero.

Then $$\frac{V_{REF}}{R_{REF}} = \frac{Vx}{Rx}$$

Since Vx is proportional to Vo then $Vo \propto Rx$

The lead resistance of Hi 1 cannot cause an error because R_{REF} is always large enough (9.9k, 99k or 9.9M) to 'swamp' the usual level of lead resistance.

The resistance of Lo 1 will not cause an error because the action Amplifier 2 is to define, at the junction of Lo 1, Lo 2 and Rx, the same potential as exists at the junction of R1 and R2. Thus the voltage caused by the reference current flowing through the Lo 1 lead resistance appears only across Amplifier 2 and has no effect on the measurement.

The resistance of lead Hi 2 and Lo 2 will have no effect on the measurement because the only current flowing along these leads is amplifier input current, which is so small as to be insignificant.

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